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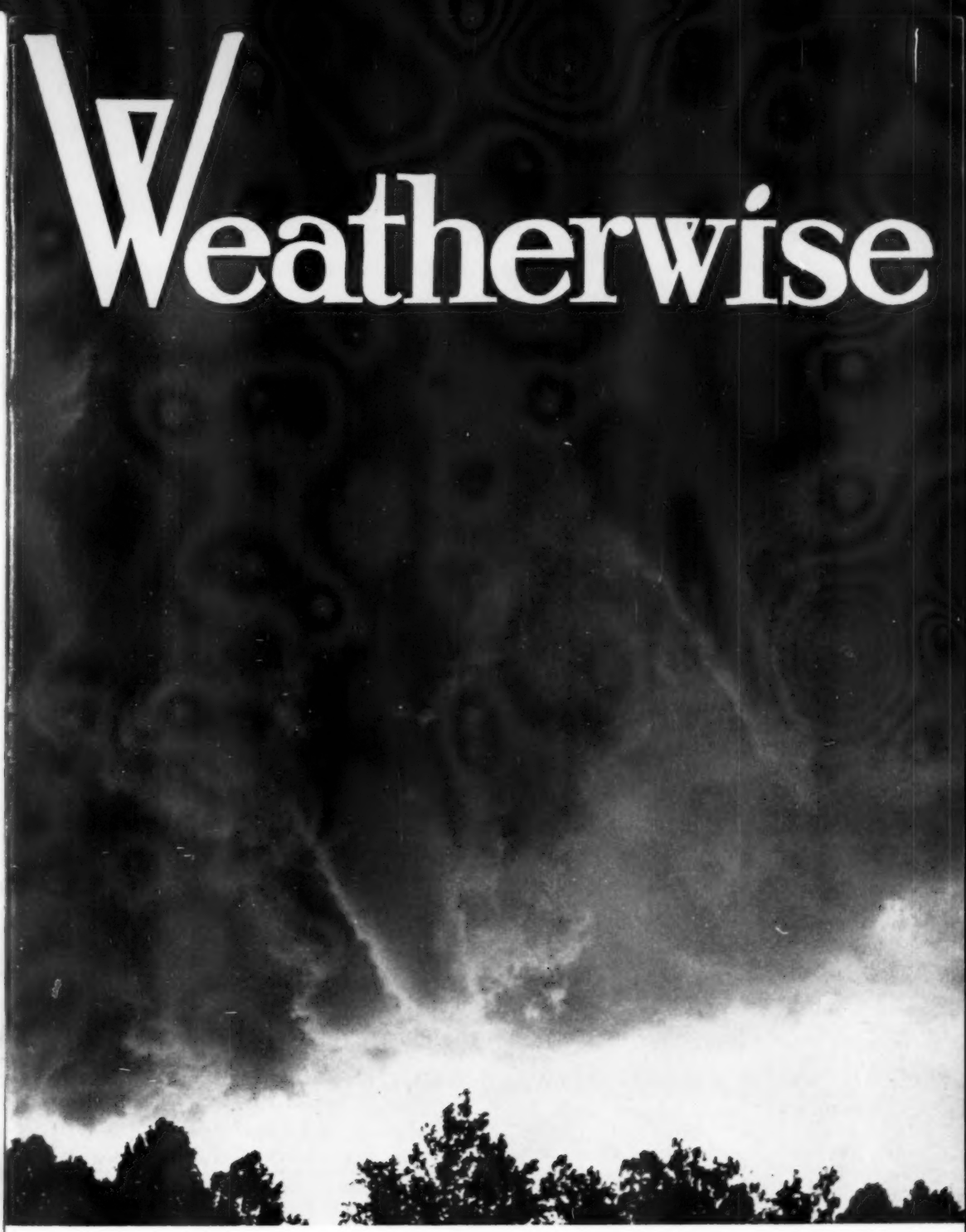

Volume 14
Number 6
December 1961

"SOME PEOPLE ARE WEATHERWISE BUT MOST ARE OTHERWISE"—BENJAMIN FRANKLIN

WEATHERWISE

THE MAGAZINE ABOUT WEATHER

DAVID M. LUDLUM, *Editor* HENRY W. BULKLEY, *Associate Editor*

Hon. Harry S. Truman Awarded Associate Membership in the American Meteorological Society on the Occasion of the 9th Weather Radar Conference, Kansas City, Missouri, 27 October 1961. Left to right: Kenneth Spengler, Executive Secretary, AMS; Don Foster, USWB, Kansas City; Harry S. Truman, Independence, Mo.; Dr. Thomas Malone, President, AMS; Hal Foster, USWB, Program Chairman; Maj. Albert Ehrlich, AWS, President, Kansas City Seminar, AMS.

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Front cover:

Funnel Clouds Over Chesapeake Bay. Photo taken at 1600, 3 September 1961, on western shore of Bay in Calvert County, Md. Camera pointed toward southeast. Funnels estimated 2–3 miles from camera. Rolleiflex camera, 1/50 sec. at F/4 Verichrome Pan film. By P. L. Hexter, Jr.

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Fallout

from the

1961 Soviet Test Series

R. J. List, L. Machta and K. Telegadas,
U. S. Weather Bureau

On 1 September 1961, the Soviet Union resumed nuclear testing in the atmosphere. By 4 November 1961, it had detonated at least 31 nuclear devices. Many were in the megaton range and two exceeded the strength of any previously announced test by any nation—25 megatons on 23 October and about 55–60 megatons on 30 October.

The role of the atmosphere in distributing the radioactive debris injected into it presents a dual meteorological problem. We must use our available knowledge to estimate where and when the debris will affect our environment and simultaneously use the measured radioactivity data to improve our knowledge of atmospheric phenomena.

TROPOSPHERIC DEBRIS

The major portion of the radioactive debris resulting from the detonation of a large nuclear device (of the order of a megaton or more) in the atmosphere is injected into the stratosphere. (If the device is detonated very near the ground, so that a large quantity of surface matter enters the fireball, a large fraction of the debris will fall out locally in the vicinity of the test site; such is not believed to have been the case in the recent U.S.S.R. test series.) A small fraction of the debris remains behind in the troposphere, of the order of a few per cent of the total. This tropospheric debris is rapidly carried around the world by the prevailing westerlies. It takes about 5 to 10 days at the 30,000-foot level to complete the circumpolar circuit. On the average, most of the tropospheric debris is removed by deposition and precipitation scavenging within a few weeks.

STRATOSPHERIC DEBRIS

The radioactive debris injected into the stratosphere consists mainly of particles so small as to have negligible fall rates. It is the fate of this debris which is of primary interest at this time. Since 1952, when the first significant stratospheric injection occurred, the U. S. Atomic Energy Commission has pursued a program to measure and identify radioactive fallout. The Department of Defense and the Atomic Energy Commission have

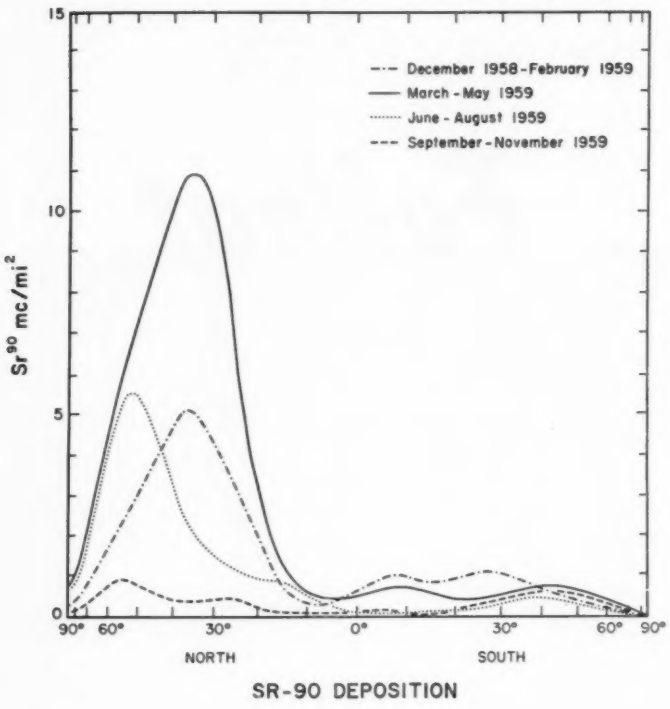

FIG. 1. Strontium-90 Deposition as a function of season and latitude.

sponsored programs to measure radioactivity in the atmosphere near the ground (1), at altitudes up to 70,000 feet by aircraft (2), and at altitudes to 90,000 feet by balloon-borne filters (3).

Results of these investigations show that debris which enters the arctic stratosphere can be expected to remain there until the following late winter and spring, when the seasonally controlled circulations of the atmosphere result in a large-scale exchange of air between the upper and lower portions of the atmosphere in temperate and polar regions. Consequently, debris which was in the stratosphere enters the troposphere, where our normal weather processes occur. Here it is acted on by removal processes and is ultimately deposited on the surface of the earth. The most important of these processes is precipitation. Rain and snow scavenge the minute particles from the air and carry them to the surface.

Figure 1 shows the deposition of strontium-90 (Sr-90) on the surface of the earth as a function of latitude and season for the period December 1958 through November 1959. The data are from the global network of precipitation samplers operated by the Health and Safety Laboratory of the Atomic Energy Commission. They consist of high-walled stainless steel pots or polyethelene funnels which collect precipitation, normally on a monthly basis. The collections in the former are sent directly to radiochemical laboratories. The funnels are used in connection with an ion-exchange resin system which removes the radioactivity from the collected water. This resin column is then shipped to the laboratory. The 1959 spring fallout peak in the north temperate latitudes is clearly seen. A similar but much smaller increase in the southern hemisphere spring is also suggested by the data. About 160 sampling sites were involved in each of the curves, 124 in the northern hemisphere and 36 in the southern. Since precipitation is the major depositing agent,

1961 USSR NUCLEAR TEST SERIES

No.	Date	Yield	Area Location	Announced By
1	Sept. 1	intermediate kiloton range	Semipalatinsk	White House
2	Sept. 4	low kiloton range	Semipalatinsk	AEC
3	Sept. 5	low to intermediate kiloton range	Semipalatinsk	AEC
4	Sept. 6	low to intermediate kiloton range	East of Stalingrad	AEC
5	Sept. 10	several megatons	Novaya Zemlya	AEC
6	Sept. 10	low to intermediate kiloton range	Novaya Zemlya	AEC
7	Sept. 12	several megatons	Novaya Zemlya	AEC
8	Sept. 13	low to intermediate kiloton range	Semipalatinsk	AEC
9	Sept. 13	low to intermediate kiloton range	Novaya Zemlya	AEC
10	Sept. 14	several megatons	Novaya Zemlya	AEC
11	Sept. 16	order of a megaton	Novaya Zemlya	AEC
12	Sept. 17	intermediate kiloton range	Semipalatinsk	AEC
13	Sept. 18	order of a megaton	Novaya Zemlya	AEC
14	Sept. 20	order of a megaton	Novaya Zemlya	AEC
15	Sept. 22	order of a megaton	Novaya Zemlya	AEC
16	Oct. 2	order of a megaton	Novaya Zemlya	AEC
17	Oct. 4	several megatons	Novaya Zemlya	AEC
18	Oct. 6	several megatons	Novaya Zemlya	AEC
19	Oct. 8	low yield range	Novaya Zemlya	AEC
20	Oct. 12	low to intermediate range	Semipalatinsk	AEC
21	Oct. 20	several megatons	Novaya Zemlya	AEC
22	Oct. 23	about 25 MT	Novaya Zemlya	AEC (detonated at about 12,000 ft.)
23	Oct. 23	low yield range	South of Novaya Zemlya	AEC (underwater detonation)
24	Oct. 25	intermediate to high range (yield probably less than a megaton)	Novaya Zemlya	AEC
25	Oct. 27	low to intermediate range	Novaya Zemlya	AEC
26	Oct. 30	55–60 MT	Novaya Zemlya	AEC (detonated in vicinity of 12,000 ft.)
27	Oct. 31	several megatons	Novaya Zemlya	AEC
28	Oct. 31	intermediate to high yield range (yield probably below a megaton)	Novaya Zemlya	AEC
29	Nov. 2	low to intermediate range	Novaya Zemlya	AEC
30	Nov. 2	low to intermediate range	Novaya Zemlya	AEC
31	Nov. 2	several megatons	Novaya Zemlya	AEC

an adjustment was made to compensate in part for the variations between the precipitation actually observed at the sampling sites and the long-term mean precipitation at the latitude of the site. This was necessary because of the lack of fallout data over oceanic and other unpopulated areas. Such corrections may be doubtful, particularly in view of the uncertainty as to the total deposition over water surface. There is some evidence (4) that such deposition may be greater than that over adjoining land surfaces.

The probable contribution of the 1961 Soviet test series to the earth's Sr-90 burden can be estimated on the basis of measurements made following the October 1958 Soviet test series. From a study of the short-lived radioactive fission products together with the Sr-90 data, it was possible to estimate the Soviet October 1958 contribution to the worldwide fallout. If the conditions of testing in 1961 were similar to those in 1958, and if the total fission yield of the 1961 test series is known, a reasonable estimate of 1962 stratospheric fallout can be made. The fission yield of the 1958 series was in the neighborhood of 10–15 megatons.

Figure 2, based on measurements following the 1958 series and upon world precipitation data shows an estimate of the contribution of the Soviet October 1958 series to the observed Sr-90 fallout. Most of this fallout, over 80 per cent, occurred within the first year following the tests, primarily in the spring rains. The greatest deposition is believed to have occurred in the heavy precipitation of the Icelandic and Aleutian lows, and virtually none in the desert regime. In the southern hemisphere, a maximum deposition of the order of one millicure per square mile of Sr-90 was tentatively assigned to the Soviet tests in areas of particularly heavy precipitation. It is very probable that the cross-equatorial transport responsible for this deposition occurred in the upper troposphere rather than in the stratosphere, either as a result of debris

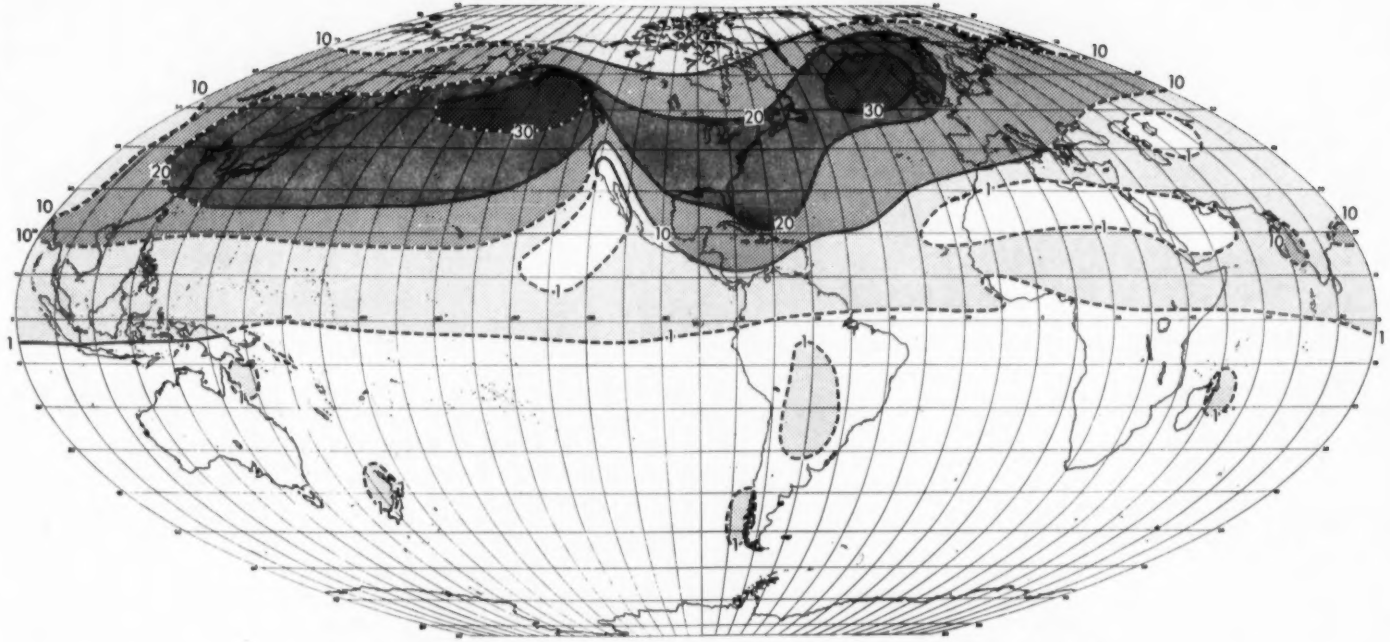

FIG. 2. Estimated deposition of stronium-90 in millicuries per square mile from the October 1958 Soviet Arctic test series, which had a fission yield 10 to 15 megatons. It is based on fallout data observed during the year subsequent to the tests and on world precipitation data. (Lines based on very limited data are dashed.)

originally injected in the upper troposphere or, more likely, as stratospheric debris which entered the northern hemisphere troposphere.

Estimates of the probable pattern of 1962 fallout from the 1961 Soviet test series can be made from figure 2. It is necessary to know the total fission yield of the new tests and to assume that the conditions of firing were essentially similar in the two series. In one sense the latter assumption appears valid, since both series consisted principally of megaton-yield atmospheric detonations. However, some caution must be used in assuming that the debris from the two large-yield 1961 tests will behave in this manner, since the resulting clouds undoubtedly rose to considerably higher altitudes and may remain in the stratosphere for longer periods. It is estimated (5) that the cloud resulting from the 55–60 megaton test rose to 140,000 feet, while clouds from tropospheric detonations of the order of a megaton are not expected to rise to more than 100,000 feet.

REFERENCES

1. Lockhart, L. B., Jr., R. L. Patterson, Jr., A. W. Saunders, Jr. and R. W. Black. *Fission Product Radioactivity in the Air Along the 80th Meridian (west) During 1959.* NRL Report 5528, U. S. Naval Research Laboratory, Washington, August 15, 1960.
2. Stebbins, A. K., III. *Second Special Report on High Altitude Sampling Program, DASA 539B.* Defense Atomic Support Agency, Washington, August 1, 1961.
3. Health and Safety Laboratory. *Fallout Program, Quarterly Summary Report, HASL-115,* U. S. Atomic Energy Commission, New York Operations Office, October 1, 1961.
4. Bowen, V. T. and T. T. Sugihara. Stronium-90 in the 'Mixed Layer' of the Atlantic Ocean, *Nature,* Vol. 186, pp. 71–72, 1960.
5. Quenneville, L. R. and K. M. Nagler. *A Note on Nuclear Cloud Dimensions,* U. S. Weather Bureau, Washington, September 1959.

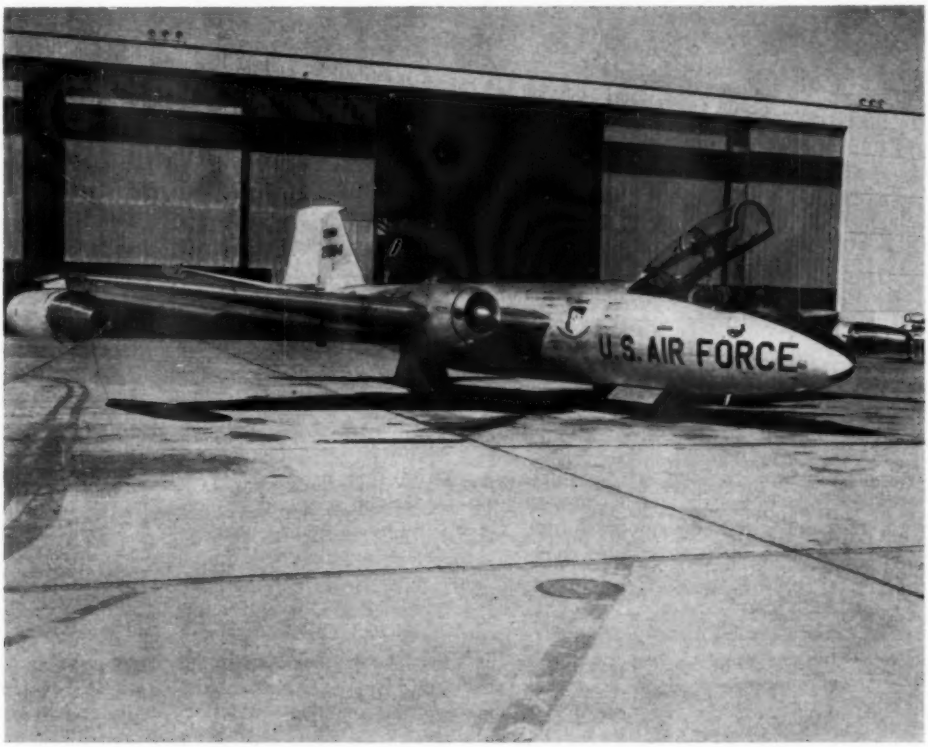

FIG. 3. USAF B-57 jet bomber of the 4926th Test Squadron (Sampling) equipped with wing-tip sampling tanks to filter radioactive particulates from the air. Each tank can be individually opened and closed from the cockpit and is capable of filtering about 5,000 standard cubic feet of air per minute. Official AF photo.

FIG. 1. Isotherm pattern for 2320 PST, 4 April 1952, superimposed on an aerial photograph of San Francisco. Courtesy of Fowler S. Duckworth, James S. Sandberg, and Spencer Duckworth.

The Temperature of Cities

J. MURRAY MITCHELL, JR., *Office of Climatology, U. S. Weather Bureau, Washington, D. C.*

MOST of us realize that the climate of cities is a bit unique. We commuters know what it is to leave our suburban homes in cool, sparkling morning air, only to arrive at work under a drab urban pall of smog. We know also, that returning home in the evening, we can expect changes along the way. In summer, we can joyfully anticipate trading insufferable urban heat for comparatively cool country breezes. In winter, we might occasionally leave the city in a bone-chilling light rain and arrive in suburbs hushed under several inches of freshly fallen snow.

THE URBAN "HEAT ISLAND"

Such urban-rural contrasts of weather and climate are due more or less directly to the fact that cities are warmer than their environs. This characteristic warmth of a city, appropriately dubbed the urban "heat island," is particularly noticeable at night when skies are clear and winds are light. Indeed the "heat island" is so characteristic of urban climate that local Weather Bureau forecasts must usually account for it with such familiar wording as, "clear tonight, low temperature 40° in the city and about 30° in the suburbs. . . .

That certain cities are warmer than their environs has been known for a very long time. London's heat island was documented by Luke Howard (1) as long ago, apparently, as 1818. More than a century later, Vienna's was described in great detail, among others by Wilhelm Schmidt (2) who in 1927 was the first to use an automobile to obtain thermal cross-sections of a city. Since then, the temperature distributions of many cities have been sampled. The example of Washington, D. C., was discussed in this magazine some 12 years ago by Landsberg (3). Undoubtedly the most exhaustive study of urban temperatures yet published is that of Sundborg (4, 5) for Uppsala, Sweden.

Duckworth and Sandberg (6) have recently surveyed the temperature distribution

of three Californian communities by automobile. Their study, the most comprehensive of its kind in the United States to date, demonstrated that relatively small towns have heat islands too. One survey, made on a clear spring night, is superposed on a photograph of San Francisco (see fig. 1) that will be familiar to many readers who recall the May, 1954 *Bulletin of the A.M.S.* On this occasion, which was far from being unique, the temperature of the densely built-up business district was some 20 F° higher than the lowest observed suburban temperature, and 7 or 8 F° higher than the average temperature of the urban periphery.

IS THE HEAT ISLAND REALLY MAN-MADE?

Most cities, it is true, were originally settled where they were because of desirable topographical features, such as a river advantageous to commerce or hills tactically valuable in their defense. Such features are certain to produce microclimatic anomalies. Someone, for example, who knows both San Francisco and a smattering of microclimatology, might well look at figure 1 and reasonably conclude that the same temperature pattern would have existed on the eve of the California gold rush in 1848, when San Francisco was a village of scarcely 800 inhabitants. After all, the highest temperatures are to be found on Knob Hill, lying above the nocturnal inversion likely to spread over the rest of the city in clear calm weather, and the lowest temperatures are in Golden Gate Park which at its minimal elevation, would be chilled the most under this same inversion.

How, then, can we know that urban "heat islands" are not topoclimatic anomalies that would exist, city or no city?

First, we can point to the fact that cities in entirely different topographic settings typically possess heat islands.

Second, we can sometimes demonstrate that the heat island of a city is weaker on Sundays when the city is comparatively dormant, than on other days of the week when it is teeming with people and bustling with activity. For example (7), a comparison of daily maximum and minimum temperatures in the city of New Haven and at its neighboring airport, averaged for four winter seasons, is shown in Table 1. The relative warmth is

TABLE 1

EXCESS WARMTH OF CITY COMPARED WITH AIRPORT (F°)

Day of week	Maximum temperature	Minimum temperature	Mean daily temperature
Sunday	+0.1	+1.2	+0.6
Monday	0.0	+2.0	+1.0
Tuesday	+0.2	+2.4	+1.3
Wednesday	0.0	+2.1	+1.1
Thursday	0.0	+2.3	+1.2
Friday	0.0	+2.4	+1.1
Saturday	0.0	+2.1	+1.0

seen to have averaged only about half as much on Sunday as on any other day. (This result is statistically significant at the 99 per cent level.)

Third, it is frequently possible to show a gradual increase of the intensity of an urban heat island as the city itself grows in size and population over the years [see (8)]. Examples are Washington, D. C., and Baltimore, Md., whose seasonal mean temperatures as measured at their downtown Weather Bureau stations, are shown in figure 2 in the form of 10-year moving averages from 1894 to 1954. For comparison, the combined temperature series for a large number of rural climatological stations, all within about 50 miles of these cities, is also shown in this figure. One can see that, especially in the summer season (at top of fig. 2), the cities have been gradually warming up in relation to their rural surroundings. Curiously, this relative warming has been almost entirely absent in winter (see bottom of fig. 2).[1]

The rates at which ten cities in the eastern half of the United States have warmed relative to their environs since the 19th Century are compared for each season in Table 2. Here, the cities have been ranked in order of growth rate, measured by the change of square root of population of each city and its suburbs. Such a measure of city growth has been used because it approximates the average length of travel over the city of air arriving at the Weather Station thermometer, and the total urban heating is assumed to be proportional to this travel distance. Table 2

[1] In passing, one may note the marked warming trend of winter climate in the Washington-Baltimore area since the 19th Century. In other seasons, warming trends adduced from the city records are attributable in large part to local urban growth, and are thus unrepresentative of large-scale climatic changes.

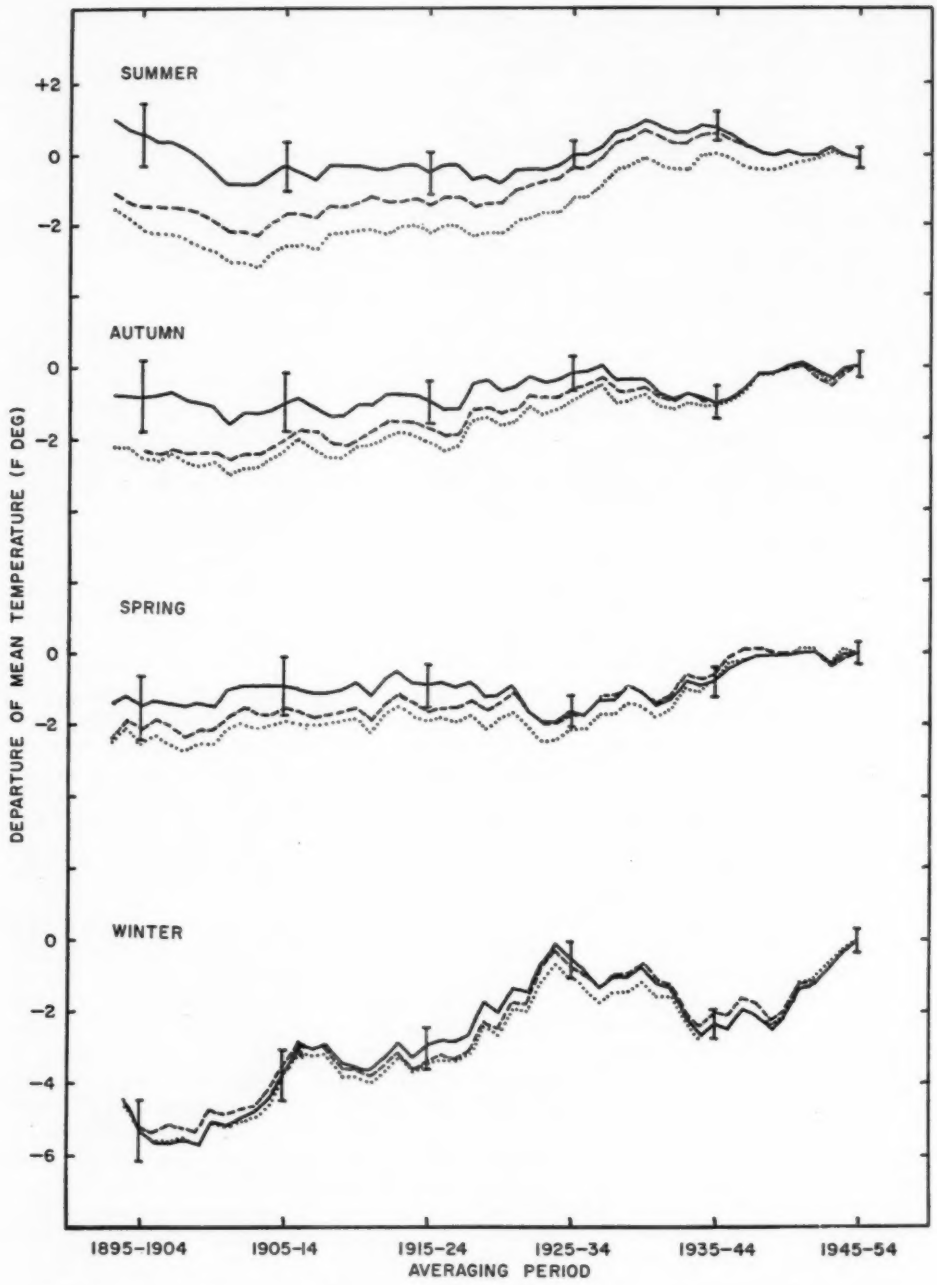

FIG. 2. Ten-year moving averages of seasonal mean temperature in eastern Maryland, shown as departures from 1945–54 average. Solid curve is average of data for 17 rural cooperative stations; dashed curve is Baltimore city data; dotted curve Washington, D. C., city data.

TABLE 2

RATES OF URBAN WARMING OF SELECTED CITIES, BY SEASONS
(All values shown are significantly different from zero at 99 per cent confidence level)

City	Period of record*	Growth rate index†	Urban warming rate (degrees F per 100 yrs)			
			Winter	Spring	Summer	Autumn
Cleveland, Ohio	1895–1941	12.9	1.8	3.8	5.1	2.7
Boston, Mass.	1895–1933	10.5	2.9	3.2	4.7	3.7
Washington, D. C.	1893–1954	9.9	‡	1.5	4.3	2.7
Tampa, Fla.	1895–1931	6.6	4.8	2.6	2.9	3.4
Baltimore, Md.	1894–1954	6.0	‡	2.0	3.0	2.7
Charlotte, N. C.	1897–1951	5.1	‡	‡	1.7	‡
Rochester, N. Y.	1914–1940	4.5	‡	‡	‡	‡
Nashville, Tenn.	1897–1948	3.0	‡	‡	‡	‡
Lincoln, Nebr.	1895–1954	2.4	‡	‡	2.2	‡
Marquette, Mich.	1899–1954	0.6	‡	‡	‡	‡

* Limited to period of available city-office data only.
† Rate of change of root population (units per year).
‡ Not significantly different from zero.

shows that, by and large, the highest rates of urban warming are associated with the most rapidly growing cities. The relationship is close in summer, as shown in figure 3, but not nearly so close in winter or for the year as a whole. A different measure of city growth would apparently be more appropriate in the colder half of the year, when the urban heat island is maintanied by different kinds of heat sources than those prevailing in summer. We will have a little more to say about these presently.

CITY-RURAL TEMPERATURE DIFFERENCES IN RELATION TO TIME OF DAY

It has already been mentioned that the urban heat island is most evident at night. Figure 4 shows comparative monthly average temperature in the center and at the edge of a city for each hour of the day. The figure refers in particular to Vienna, Austria, for which hourly mean temperatures are readily available (9), but there is no reason to doubt that data for American cities would show similar comparisons.

In July, the relative warmth of the city is largest at night, and virtually absent during most of the daytime. In fact, during midday in summer, it is not unusual for the city to be a fraction of a degree *cooler* than its environs, owing presumably to the attentuation of sunlight over the city by dust and smoke. The city continues to hold its heat in the late afternoon, after temperatures have begun to slide in the suburbs. Maximum

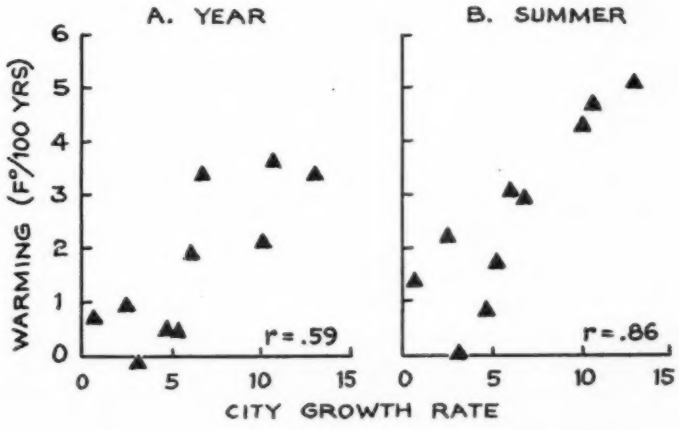

FIG. 3. Change of urban temperature with city growth: annual mean temperature on left, and summer-season mean on right. Cities are those listed in Table 2. "r" is correlation coefficient.

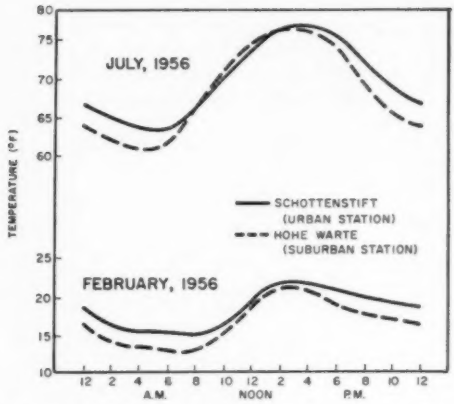

FIG. 4. Diurnal variation of temperature in Vienna, Austria.

daily temperatures in the city may thus be reached an hour or two after they are reached in the suburbs. Minimum temperatures are also reached somewhat later in the city, and the daily temperature range is smaller in the city.

In February (the coolest month of the year in Vienna), the city tends to remain warmer than its suburbs both day and night. Again, the daytime differences are smaller than the nighttime ones. Daily maxima and minima of temperature are reached slightly later in the city than in the suburbs, and the daily range is less in the city.

CITY-RURAL TEMPERATURE DIFFERENCES IN RELATION TO TIME OF YEAR

Figure 5 shows two examples of the annual march of temperature in and outside cities. Comparative monthly normals of daily maximum, mean, and minimum temperature are included in this figure. These examples are typical in showing the urban heat island to be reflected most in minimum temperatures, and least in maximum temperatures, throughout the year.

CONTRIBUTORY CAUSES OF THE HEAT ISLAND

Various physical factors are probably responsible in part for the formation of urban heat islands. Some are more influential in summer, and others more so in winter.

On a summer day, solar radiation is more or less readily absorbed in the city by building and paving materials possessing large heat storage capacities. There is virtually no vegetation or moist soil that can soak up some of this solar heat by evaporation, as it does in the country. The temperature of streets and south-exposed building surfaces may soar well above 100°. Even though air temperatures may be reasonably low, these hot surfaces irradiate us poor pedestrians, seemingly like so many turkeys in a slow oven! To make matters worse, the buildings break up the cooling breezes that might otherwise offer relief.

As night falls, the streets and buildings begin to cool down, but ever so slowly. Their radiation continues all night, and their elevated temperatures prevent the air itself from cooling as much as it otherwise would. By morning, this heat has still not entirely expended itself, and the next sizzling day begins with this thermal handicap.

On a winter day, matters are a bit different (in our relatively high latitudes). The solar rays may have appreciable heat in them, but the streets and buildings are warmed perhaps as much by the furnace heat of our office buildings and homes. This heat seeps through their imperfectly insulated walls and windows and disgorges through countless rooftop chimneys.

During the day, the atmosphere is comparatively turbulent, and the urban warmth is dissipated before street-level temperatures can be much affected. By nightfall, however, the furnaces begin to work harder against the cold, and the increasing sluggishness and stability of the atmosphere allow their heat to accumulate more readily in the city. In addition, the smoke, water vapor, and carbon dioxide escaping from the chimneys spread out in a "blanket" above roof-level that augments the building walls themselves in intercepting some of the heat radiation from the streets and re-radiating part of their own heat downward. Under these circumstances, temperatures remain relatively high in the city throughout the night, all the way from street level to heights often considerably above the roof tops [see (6)].

Surmounting this warm layer, a nocturnal inversion is commonly encountered. This inversion inhibits the upward dispersion of

smoke and other pollutants in the city. In fact, the inversion may become intensified by the pollution layer whose upper surface cools by radiation to the sky, just as in the country the ground itself cools by radiation. This, in turn, promotes the further increase of pollution concentration in the city, until arrival of morning when the sun's heat can finally destroy the inversion.

EFFECT OF GENERAL WEATHER CONDITIONS ON THE HEAT ISLAND

In the preceding discussion, we have been presupposing average weather conditions, characterized by relatively clear skies and light winds. Since cloudiness and strong winds would inhibit the formation of ground inversions, and since wind speed would also affect the rate of "ventilation" of the city, it is to be expected that the intensity of the urban heat island would depend substantially on these weather variables. Sundborg (4), who studied the matter in some detail for Uppsala, found that the nighttime urban-rural temperature difference, D, could be roughly approximated by an equation of the form

$$D = \frac{a - b\,N}{V}$$

where N is per cent cloud cover, V is wind speed, and a and b are constants. Undoubtedly such a formula could be used for cities other than Uppsala; appropriate values of the constants would depend on the city and on the locations of the wind speed and comparative temperature measurements.[2]

In this article it has been possible merely to sketch in some of the salient characteristics of the urban heat island. The interested reader will find many further details in the references already cited, especially those of Sundborg, and Duckworth and Sandberg. A comprehensive account of all aspects of the climate of cities has been given by Landsberg (10).

[2] Note that calm winds would have to be treated as a special case (in Uppsala, calms were rare). Sundborg also found that temperature itself, and humidity, influence D somewhat. At night, however, these factors are negligible in comparison with wind and cloudiness.

Yes, the climate of our cities is assuredly a little unique. Man has himself to thank—or blame—for that! In retrospect, how could he change the face of the earth so drastically, as he does building his cities, and expect otherwise? Too, how could he spill all the heat and pollution that he does into the urban atmosphere, and expect otherwise?

REFERENCES

1. Howard, L. *Climate of London Deduced from Meteorological Observations.* Harvey and Darton, London (3rd Ed.), 1833.
2. Schmidt, W. Distribution of Minimum Temperature during the Frost Night of May 12, 1927 within Vienna. *Fortschritte der Landwirtschaft,* 2–21, 1929, 681–686. (In German.)
3. Landsberg, H. E. Comfortable Living Depends on Microclimate. *Weatherwise,* 3–1, 1950, 7–10.
4. Sundborg, Å. Climatological studies in Uppsala with Special Regard to the Temperature Conditions in the Urban Area. *Geographica* (Geographical Institute, University of Uppsala,) 22, 1951. (111 pages.)
5. Sundborg, Å. Local Climatological Studies of the Temperature Conditions in an Urban Area. *Tellus,* 2–3, 1959, 222–232.
6. Duckworth, F. S., and J. S. Sandberg. The Effect of Cities upon Horizontal and Vertical Temperature Gradients. *Bulletin American Meteorological Society,* 35–5, 1954, 198–207.
7. Mitchell, J. M., Jr. On the Causes of Instrumentally Observed Secular Temperature Trends. *Journal of Meteorology,* 10–4, 1953, 244–261.

(*Continued on page 258*)

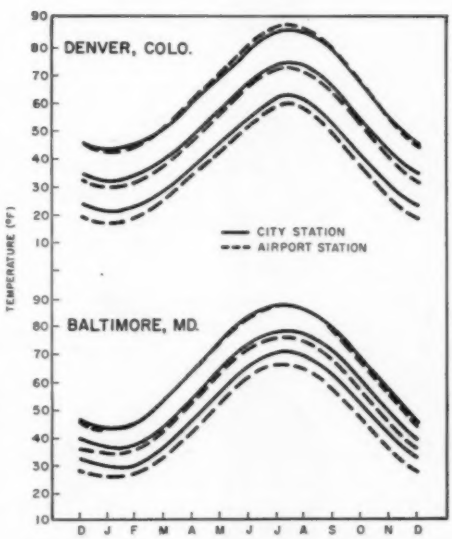

FIG. 5. Annual variation of average monthly maximum, mean, and minimum temperatures in and outside selected cities.

An Explanation of the Limitations to the Coverage Provided by TIROS

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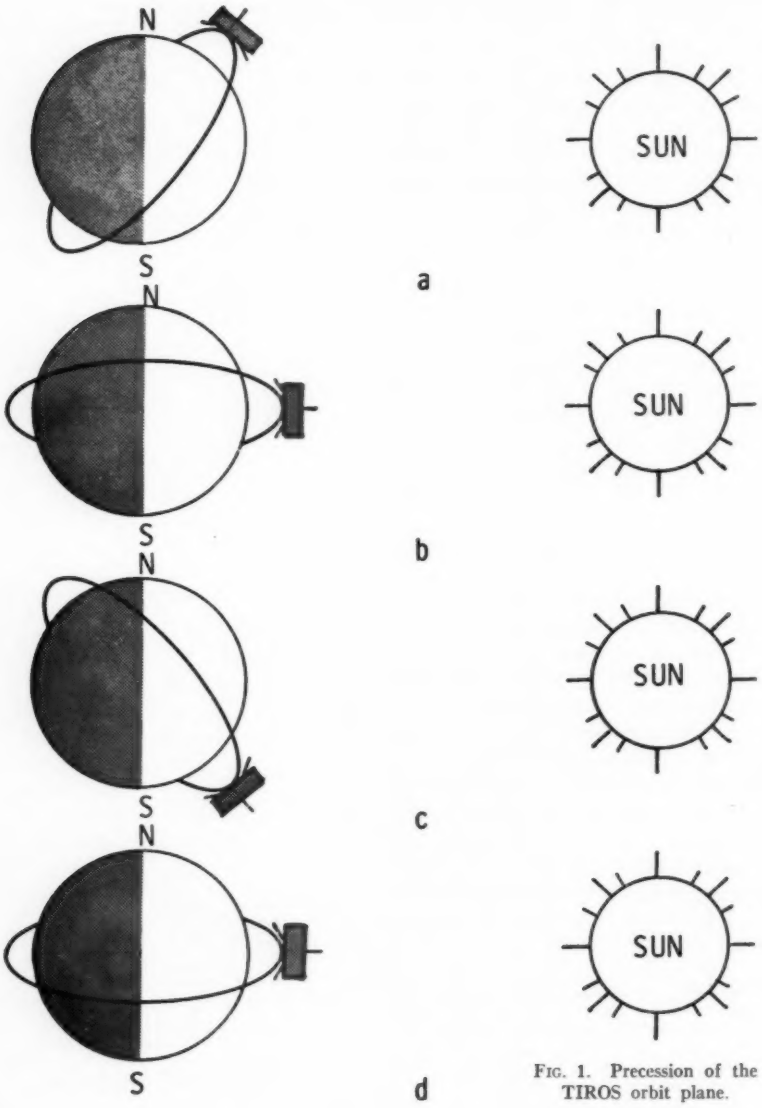


FIG. 1. Precession of the TIROS orbit plane.

MANY meteorologists desiring to use cloud picture data from NASA's TIROS satellites, whether for current weather analysis and forecasting or for research studies, have wondered why the data may not be available for a particular time and place, especially in the case of a significant storm. A number of factors limit the geographic areas over which a TIROS satellite can make photographic observations. Some of these, such as the inclination of the satellite's orbit, the requirement of solar illumination for photography, data storage capabilities, and camera attitude, are generally understood. But two factors, precession of the orbit with respect to the sun and the locations of the data read-out stations, are somewhat more subtle. The following discussion provides an explanation of these limitations and describes a method for determining when TIROS photographs may be taken over specific geographical areas. Samples of the maps and graphs that are used in such determinations are provided.

LATITUDE LIMITATIONS

Because the earth (in common with more than a few meteorologists) has a slight bulge at its equator, the plane of the satellite's orbit precesses in Right Ascension (astronomical longitude) at the rate of a few degrees per day. Detailed descriptions of the cause of the precession and graphs from which the rate (which depends on orbit inclination and altitude) can be determined can be found in several sources, such as King-Hele's book. As a consequence of this rate of precession and the movement of the earth in its own orbit around the sun, a complete cycle of this precession of the plane of the satellite's orbit relative to the sun is completed in about nine weeks. This imposes latitude limits on the areas of photographic coverage because of the requirement for solar illumination.

In attempting to visualize these phenomena and their effects on the availability of observations over a given area, it is necessary to recall that for any single day the plane of the orbit remains nearly fixed in absolute space and relative to the sun, while the earth rotates independently within the orbit. Thus, on any single day, from the viewpoint only of solar illumination, the same latitudes at all longitudes could be observed by the cameras at various times during a 24-hour period. However, the locations of the read-out stations place an additional constraint on observable longitudes (see next section). The slow precession of the orbit plane causes the illuminated latitudes as seen from the satellite to change, over a nine-week cycle, as described below.

The times of Tiros launch have been so chosen that the northern part of the orbit is on the side of the earth nearest the sun (as shown in fig. 1a) and the TV cameras can obtain data over latitudes from about the equator to 50°N latitude. (At this time, the satellite is over the southern hemisphere only at night.) Gradually, the high noon point of the orbit moves slowly southward until, about one week after launch, the descending node (point where the orbit crosses the equator on the southbound leg) is on the same side of the earth as the sun (fig. 1b). At this time, photographic observations are made in the regions approximately between 35°N and 35°S latitude.

Precession of the orbit and southward movement of the illuminated area under the orbit continue until, about 3½ weeks after launch, the southern part of the orbit is on the side of the earth nearest the sun and photographic data can be obtained between about 20°–50°S latitude, but not in the northern hemisphere over which the satellite passes now only at night (fig. 1c). From this point, the precession causes the illuminated portion of the orbit gradually to move northward; about six weeks after launch, the ascending node (point where the orbit crosses the equator on the northbound leg) is on the same side of the earth as the sun and again the observable latitudes are primarily in the tropics (fig. 1d). Continued precession and northward movement of the illuminated area under the orbit reach the point, about eight weeks after launch, where the northernmost portion is again over the side of the earth nearest the sun and photographic observations again are possible between 20°–50°N latitude (fig. 1a). Precession continues and now southward movement of the illuminated area under the orbit begins again with the whole cycle repeating about every nine weeks throughout the useful life of the satellite.

The consequences are graphically illustrated in figure 2, on which the shaded area indicates,

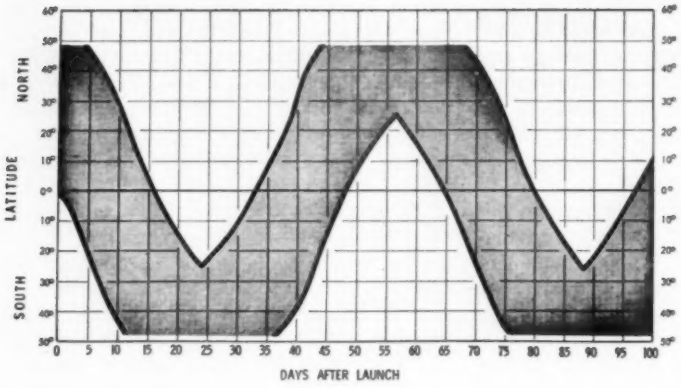


FIG. 2. Illuminated latitudes.

for each date on the abscissa, the illuminated latitudes. For use in determining the areas of photographic coverage, the data on this graph are displayed in two parts such as figures 2a and 2b. Figure 2a shows the illuminated latitudes on the *southbound* portions of the orbits while figure 2b shows this for the *northbound* portions.

LONGITUDE LIMITATIONS

Within the illuminated latitude zone there are also longitude limitations upon the areas from which data may be obtained. The locations of the read-out stations (Virginia and California) determine the extent of these limitations for the following reasons:

(1) The data storage capability of the satellite is limited (discussed in a later section), and

(2) The range at which each station can contact the satellite and usefully read-out data is limited to line of sight.

When plotted on a Mercator projection world map such as figure 3, the trace of the orbit subpoint describes a sine-shaped curve, centered on the equator, with a half-amplitude of just under 50° of latitude and a wavelength of approximately 335° of longitude. The 335° wavelength derives from the rotation of the earth under the satellite; the longitude of each ascending node being displaced approximately 25° west of that for the immediately preceding orbit. The range at which each data read-out station can contact the satellite and usefully read-out data is a circle with a radius of about 20° of latitude.

Orbits with ascending nodes over the area of the Atlantic Ocean cannot be contacted by either data read-out station; in fact, the first

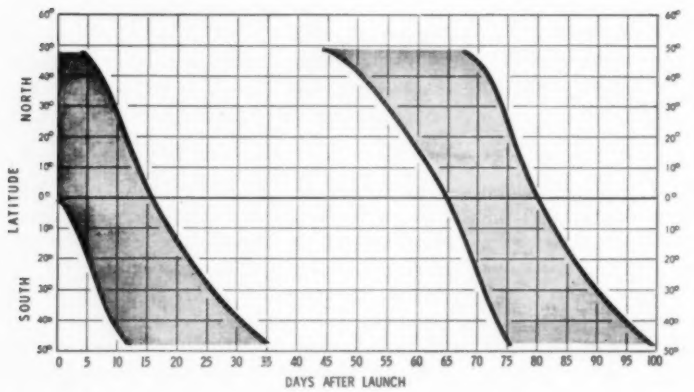


FIG. 2a. Illuminated latitudes (southbound passes).

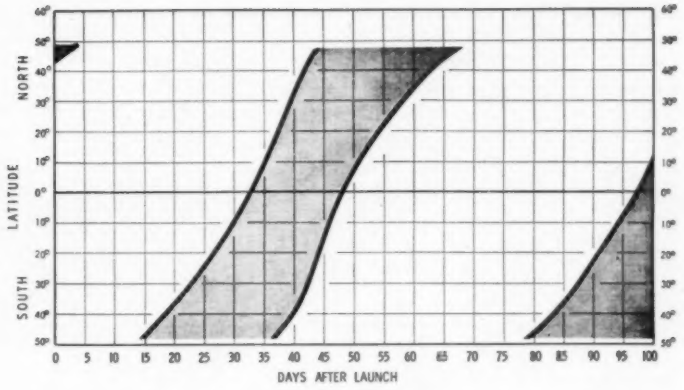


FIG. 2b. Illuminated latitudes (northbound passes).

orbit following these that can be contacted has an ascending node of about 75°W longitude (Orbit A, fig. 3) and can be reached by the Virginia station near the southeastern extremity of its range. (The following discussion relates to a 24-hour period starting with this orbit.) Following this orbit the next seven orbits can also each be contacted by either the Virginia or California stations (or both), the last one being that with an ascending node near 80°E (Orbit B), which is contacted by the California station, near the southwestern extremity of its range, shortly before its descending node near 115°W. During this 7½ orbit period, station locations impose no limit on the amount of data that can be obtained. The area covered during this 7½ orbit period is defined as Area I and is the most favorable area for photographic coverage.

During the approximately 6½ orbits between the last contact with the California station and the next contact with the Virginia station (about 24 hours after the first contact

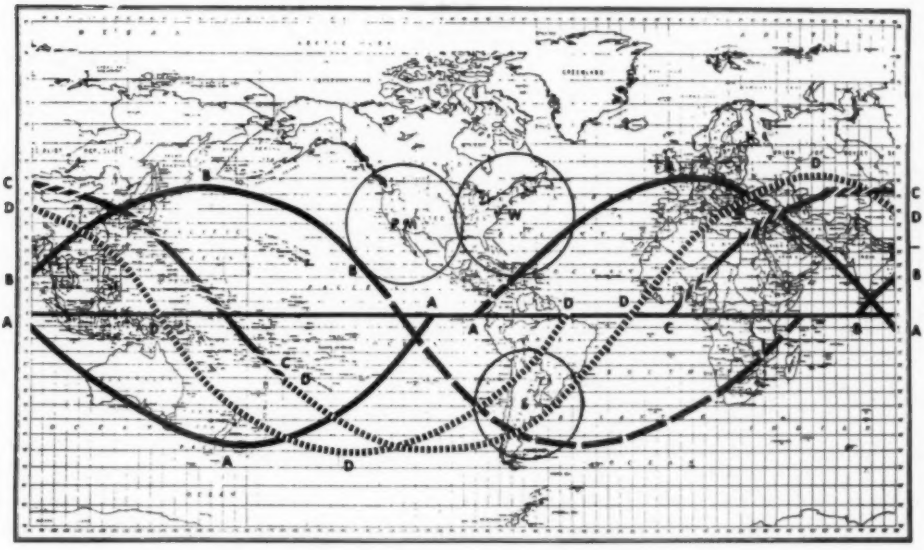


FIG. 3. Orbit subpoint traces.

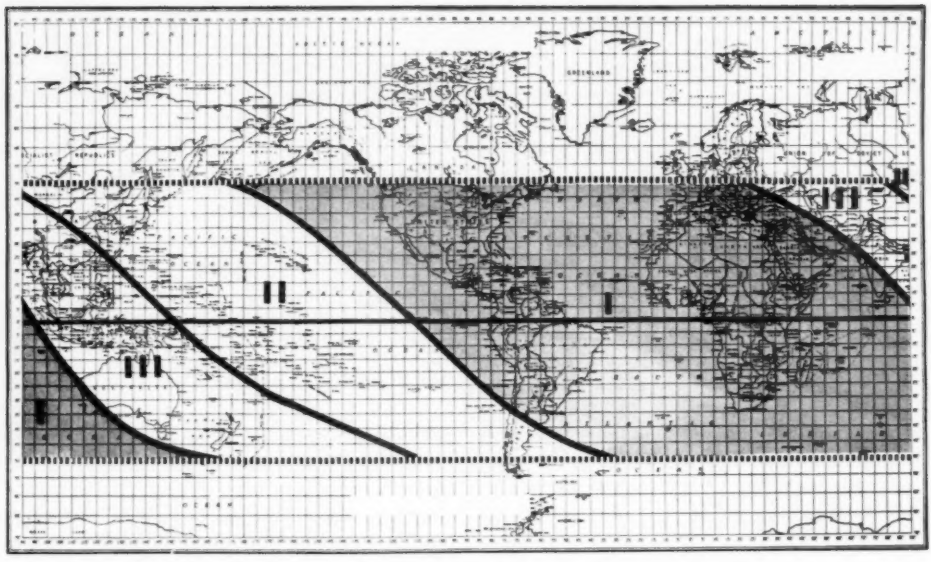


FIG. 4a. Areas defined by longitudinal limitations: Southbound passes.

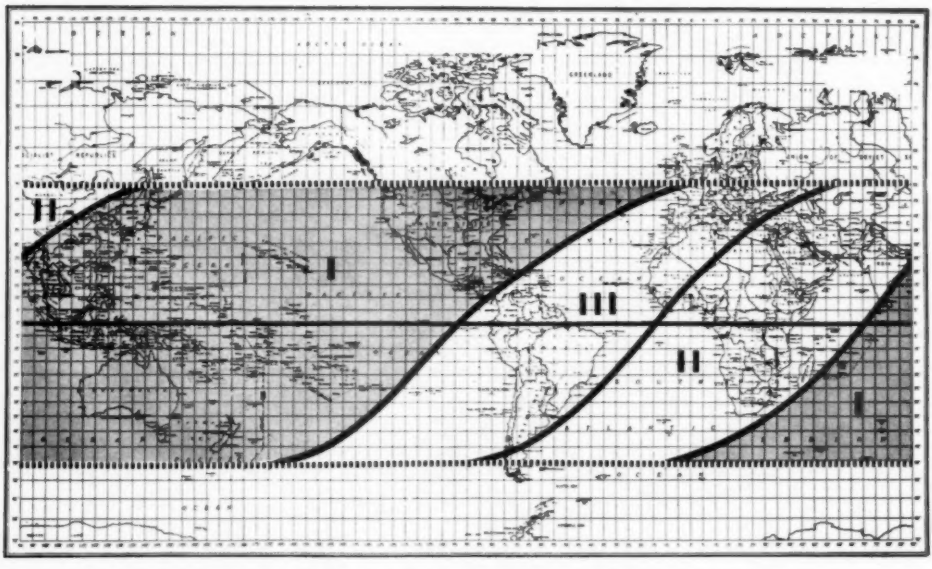


FIG. 4b. Areas defined by longitudinal limitations: Northbound passes.

with the Virginia station, which started the period under consideration), TIROS can obtain:

(1) One sequence of 32 pictures from each of the two cameras during this entire period.
(2) Infrared radiation data for the last 100 minutes before the Virginia station contact.

The areas covered during this 6½ orbit period include Areas II and III (defined below) and are less favorable for photographic coverage.

REMOTE PROGRAMMING

An additional factor even further limits the data that can be obtained during this 6½ orbit period of time. The satellite clocks, which determine when remote picture sequences will start, can run for a maximum of only three orbits (five hours) after being started before they initiate the picture-taking sequence. Under normal operating modes, this limits picture data following the last California contact to the area between this contact (just before the 115°W descending node on Orbit B) and five hours and 15 minutes later (shortly after the descending node at approximately 165°E longitude on Orbit C). The area covered during this three-orbit (five hour) period following the last contact with the California station is defined as Area II. From this point on, no pictures could, under normal operating modes, be taken until the first Virginia contact on the orbit with an ascending node between 75°W and 100°W.

To overcome this limitation, a supplemental mode of operation was used for the first time during the TIROS III experiment. The clocks were set during the last California contact (such as Orbit B) but, if not started then, could be started by a special signal transmitted from the NASA Minitrack Station at Santiago, Chile. This mode permits pictures to be taken from the time an orbit comes within range of Santiago (such as Orbit D) until the next contact with the Virginia station. This special mode has been established primarily to increase the opportunities of obtaining tropical storm data over the tropical North Atlantic and was used to obtain data on Hurricane Betsy, but can be more widely applied. The area over which pictures can be taken using this special mode (Santiago clock start) is defined as Area III.

This special mode of operation can in no way increase the amount of picture data that can be obtained during the 6½ orbit time period (Areas II and III) following the last California contact; it only permits more flexibility in choosing the areas over which the one picture sequence per camera is taken.

The areas (II and III) affected by this limitation of one series of pictures per camera per day are approximately as follows (as can be seen in Figures 4a and 4b):

(1) *On southbound portions of the orbits.* From a line, running approximately from the southern tip of the Kamchatka Peninsula southeast to South Georgia Island (South Atlantic Ocean), westward to a line running from Hungary southeast to near the southern tip of New Zealand.
(2) *On northbound portions of the orbits.* From a line, running from Sakhalin Island (north of Japan) southwest to about 50°S, 0°; westward to a line running from the English Channel to about 50°S, 165°W.

It should be noted that most of these areas are also covered by orbits in the other phase which are contacted once per orbit by the Virginia and/or California stations. This is not true, however, for an area over central, southern and southeastern Eurasia, and for another over the southeastern Pacific Ocean and southern Argentina and southern Chile; consequently, the amount of data that TIROS can obtain over these latter areas is severely limited.

USE OF GRAPHS AND MAPS

To determine when pictures could be taken of a specific area, first determine the latitudinal limits of the area in which you are interested. Then, using figure 2a, determine when these latitudes are illuminated for southbound passes. From figure 2b, make a similar determination for northbound passes. These are the approximate periods when it will be possible to take pictures over this area. Of course, other limitations, discussed later, preclude taking data over all areas at all times.

In many parts of the world, the period of southbound passes is more favorable than that of northbound passes, or vice versa. To determine this, use the maps (figs. 4a and 4b). These maps show the geographical limits of Areas I, II and III for southbound passes (fig. 4a) and for northbound passes (fig. 4b). Area I is the most favorable; next most favorable is Area II. Area III provides the least favorable probability of obtaining pictures from the satellite. It is roughly estimated that the probability of pictures being taken in Area I is about five times greater than in Area II and III combined. Similarly, it is estimated that the probability in Area II is about twice as great as that in Area III.

EXAMPLE

Consider, as an example, the case of that part of Brazil between the equator and 30°S latitude. On the southbound portions of the orbits, the northern part of the area is under an illuminated portion of the orbit from shortly after launch until about the 16th day after launch and again from about the 65th to the 80th day; the southern portions from about the 7th to the 26th day and again from about the 71st to the 90th day. On the northbound portion of the orbits, the southern part of the area is under an illuminated portion of the orbit from about the 23rd to the 42nd day and again starting about the 87th day; the northern portions from about the 33rd to the 48th day and again starting about the 97th day. However, Brazil is under Area I (most favorable conditions) for southbound portions of the orbit while it is under Area III (least favorable conditions) for northbound portions. Accordingly, the most favorable periods for TIROS pictures over Brazil would be during the two 16-day periods centered about the 12th and 76th days after launch when Brazil is under an illuminated southbound portion of the orbit. There is much less chance of pictures being obtained during the periods centered on the 37th and 100th day after launch; although illumination is satisfactory, Brazil is under those portions of the orbit that can be programmed only using the special Santiago clock-start mode.

DERIVATION OF MAPS AND GRAPHS

The sample graphs and maps presented here were derived using a nominal TIROS orbit (380 nautical mile orbit altitude; 48.5° orbit inclination) and relate specifically to the prelaunch design characteristics and objectives of TIROS III. They are approximately valid, however, for the actual orbits attained by TIROS I, II, and III. If subsequent TIROS satellites are launched into higher inclination orbits, as is under consideration at the time this is written, adjustments would be necessary due to the poleward extension of the viewable latitudes and the change of the rate of orbital precession as a function of the orbit altitude and inclination.*

An overlay of the satellite track superimposed on a Mercator projection of the earth was used. The "high noon point" of the satellite orbit (that is, the point in any orbit at which the subsatellite point on the earth crosses the meridian of local high-noon) is determined from the difference in Right Ascension (astronomical longitude) between the sun and the ascending node of the orbit. It is assumed that the minimum nadir angle (zero) occurs at this point—that is, the cameras are pointing straight down—and that the 30-minute illuminated area for a picture-taking sequence (one full 15-minute sequence per camera) commences 15 minutes before this point on the orbit and is completed 15 minutes after the high-noon point.

There are potential variations in the boundaries in the graphs and maps of 25° in longitude and 6° in latitude. The longitude may vary because of differences in the position of the first and/or the last orbits that can be interrogated by the two read-out stations. Both the longtiude and latitude may vary dependent upon camera attitude.

During the TIROS III International Cooperation Period (8 August through 10 October 1961), more accurate photographic programming information was placed on international meteorological communications networks seven days in advance and again 24–48 hours in advance.

ASSUMPTIONS

As mentioned above, the assumption has been made that the minimum nadir angle

* The fourth TIROS will be launched into an orbit similar to that of TIROS I, II, and III. Higher inclination orbits are still under consideration for the fifth and subsequent TIROS.

(zero) occurs at high-noon on the orbit and that the photographic sequence of the two cameras will evenly bracket high-noon. In addition it has been assumed that the satellite spin axis vector is in the orbital plane. In actual operation, the position of the minimum nadir angle will vary and the spin axis vector will generally be somewhat out of the orbital plane. A number of the picture sequences are taken before or after high-noon on the orbit in order to furnish a number of pictures with horizons to facilitate determination of attitude through photographic techniques.

Thus it is possible under some conditions to obtain a limited number of pictures north of 48° North and south of 48° South, the extreme orbital subpoints. However, the probability of data being obtained decreases when proceeding poleward of these latitudes.

OTHER LIMITATIONS

For the benefit of those readers who may be less familiar with the design of the TIROS satellites, the other factors which limit the data that can be obtained are summarized:

Orbit inclination: Because the orbit of the satellite is inclined at an angle of slightly less than 50° to the equatorial plane, the satellite is unable to gather significant meteorologically useful data polward at about 55°N and S. latitude.

Spin stabilization: For all practical purposes, the orientation of the spin axis of the spacecraft remains fixed in absolute space over any one orbit (the rate of change of the spin axis orientation due to use of the magnetic control coil cannot exceed about 15° per day). Accordingly, even under the most favorable circumstances with regard to the orientation of the spin axis and the position of the sun, the TV cameras are pointed toward illuminated portions of the earth over only about one-third of each orbit. The interaction of the satellite with the magnetic field of the earth, discussed by Bandeen and Manger, keeps the cameras pointing approximately to the nadir near the high-noon point of the orbit, regardless of whether this occurs in the northern or southern hemisphere.

Magnetic tape storage capacity:

a. *Photographic data:* During the period between the programming of a camera for remote (storage) picture operation and the reading out of the data from that camera's tape recorder, only one set of 32 remote pictures, taken sequentially at 30 second intervals, can be obtained by a camera system. The overall length of the area observed during one sequential strip of 32 pictures is of the order of 6000 miles (9600 km), at best. Accordingly, between successive contacts with the command and data acquisition stations, at best only two such sets of 32 pictures can be taken, one by each camera system.

b. *Radiation data:* Because these data are recorded on a continuously running endless loop magnetic tape which completes its cycle in about 100 minutes, data older than 100 minutes are erased as newer data are recorded. Thus, only data observed within 100 minutes before data read-out by a ground station can be obtained.

Power: At times the rate of power provided by the solar cells is insufficient to permit the taking of as many TV pictures as would otherwise be available. The extent of this constraint varies with the precession of the orbit plane and the orientation of the satellite spin axis. In addition, available power gradually decreases as the nickel-cadmium storage batteries degrade with age and with repeated charge-discharge cycles.

REFERENCES

Bandeen, W. R., and W. P. Manger, 1960: "Angular Motion of the Spin Axis of the TIROS I Meteorological Satellite Due to Magnetic and Gravitational Torques." *Journal of Geophysical Research, 65* (9), pp. 2992–2995.

Fritz, Sigmund, 1959: "On Observing the Atmosphere from Satellites—I. Cloud Observations." *Weatherwise, 12* (4), pp. 139–144, 163–165.

King-Hele, Desmond, 1960: *Satellites and Scientific Research*, Dover Publications, Inc., New York, pp. 16–21.

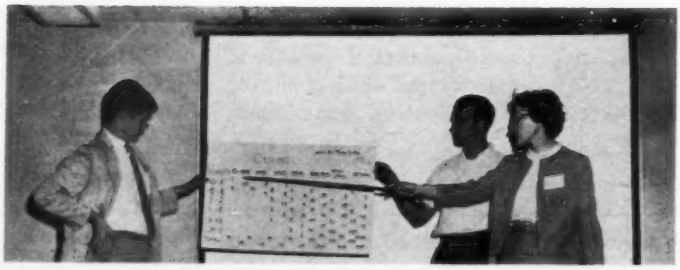
Tepper, Morris, 1961: "A Report on the Meteorological Satellite Program." *Weatherwise, 14* (4), pp. 131–137, 168.

Tomorrow's Scientists Exp

John Houghton (seated), Stanley Sigler (left), and James Lish checking the observational instruments in the weather console at the USWB airport station in Salt Lake City. Courtesy *The Salt Lake Tribune*.

A NATIONWIDE student trainee program is one of the United States Department of Commerce—Weather Bureau's answers to the exacting and expanding challenge of the atmospheric sciences. With all phases of science facing a vast mushrooming of knowledge, summers spent in the trainee program give insight and orientation in the field of meteorology otherwise unattainable.

Trainee positions are open to students from high school graduation until they finish college. They must be majoring in meteorology or planning to do so. At the present time they are required to enroll in a program leading to a Bachelor's degree in meteorology by their third year of college. However, an expected change will allow those who are pre-



Susan L. Staley of Duke University, assisted by Richard M. Wheeler (left) of Johns Hopkins University, and William E. Shenk (right) of Pennsylvania State University, in her presentation to the Washington, D. C. Student Trainee Seminar on 28 August 1961.

Robert Anderson operating the cloud height radar at Washington National Airport.

Louise Habicht at the console of the IBM 7090 in the Joint Numerical Weather Prediction Unit at the National Meteorological Center, Suitland, Maryland.

Explore Weather Bureau Today

GEORGE HATZENBUHLER, *Assistant Chief, Training Section, United States Department of Commerce, Weather Bureau*

paring for graduate study in meteorology by undergraduate specialization in mathematics, physics, and other related sciences, to continue in the program. The majority of these students are now given temporary summer appointments. Engineers and certain other specialized students are also included in this way for some of the career fields which support the main weather mission. Possible assignments are available at over 300 locations throughout the country.

Student trainees receive Civil Service appointments. While on duty, their salaries range from $67 to $77 a week. During the school year, trainees are on leave and do not receive pay. Upon graduation, they may enter regular career assignments and receive all Civil Service benefits that have accrued from the time they have spent on the job.

Our primary objective is to stimulate young people to enter careers in meteorology. Every effort is made to provide a program which will utilize the student's full potential, and to give him an opportunity to apply what he has learned at school. To meet this objective, the trainee's supervisor works up a schedule at the beginning of each summer. This may include work assignments which directly help the Bureau provide its service, study assignments and on-the-job training. The supervisor is encouraged to assist the trainee in every way possible and to provide as many professional experiences as the station program will afford. When a number of students are assigned to one location, orientation programs and student seminars are conducted. These help the trainee to understand the organization and to see other facets of meteorology in action. The seminars give them the opportunity to express their views, present papers, and to engage in group discussions with colleagues. Each year trainees are encouraged to write about their experiences during the summer, either in the form of a report or a research paper covering the activity with which they have been working. These are presented in a printed report which is dis-

Kevin D. K. Pang of the University of Hawaii operating the ice-nuclei counter at Hilo Station of Mauna Loa Observatory, Hawaii.

1961 orientation program for student trainees in the Washington, D. C. area included trips to the National Airport, National Meteorological Center, and Instrument Engineering Division in the two-day program.

tributed at the end of the year to all student trainees, Weather Bureau stations, and university meteorology departments. Here are a few excerpts from some of the reports that may be of interest to young people considering meteorological careers.

James E. Lovill, of Florida State University, became interested in meteorology as a cooperative observer and learned about the trainee program from *Weatherwise*. After a summer at Bristol, Tennessee, he wrote: "I found just what I wanted, i.e., on-the-job training with pay. . . . I wouldn't trade this summer work for any other kind. . . . When next summer rolls around, I hope to be assigned to a station equipped with radiosonde for upper-air observations."

John T. Curran, Jr., of St. Benedict's College, who learned about the program at the college placement bureau, says: "I thought it would be an interesting job and also offer an excellent way to determine if I should make a career of meteorology. My supervisor, Mr. Edward F. Stapowich (in charge of the Weather Bureau station at Omaha) spent much of his time explaining the various functions of the Weather Bureau. His enthusiastic outlook for the future of the Weather Bureau stimulated me and influenced my decision to make meteorology a career. I appreciate (his) . . . frankness in pointing out both the advantages and disadvantages of Weather Bureau work."

It did not take August H. Auer, Jr., of Florida State University, long to find a place for himself. ". . . Within a month I was placed on the working shift with other observers. . . . During the slower hours of the late evening and early morning, the radar man would instruct me on the basic concepts involved in taking radar observations and data interpretations (storm paths, precipitation intensity, cloud heights, etc.) of the WSR-57 radar set at St. Louis."

Donald L. Finch, of the University of Utah, comments on the value of being at a station with a state climatological program, such as Albuquerque, New Mexico: "The majority of my time . . . was spent in learning to take observations, both surface and upper air. . . . I spent a few days working with the state climatologist . . . I believe this should be one of the first things on the student trainee's agenda, as this provides him with the opportunity to familiarize himself with climatic conditions corresponding to terrain and season in the state to which he is assigned.

"How has working for the Weather Bureau aided my school work and vice versa?" asks J. William Wantz, University of Washington. "The summer of 1961 marked the third summer I have worked for the Weather Bureau, and the first in Seattle. . . . The Bureau represents the workshop where the tools learned at school are utilized. This is especially true of material learned in courses dealing with observations, instruments, forecasting, and atmospheric physics."

Last summer Claude B. Graves of the University of Washington finished four years as a trainee. "About the student trainee program in general, I can say that it helps one quite a bit in school, especially in courses which deal with climatology and synoptic meteorology. The main advantage to the program as a whole is that I have been given training in a wide range of duties which will enable me to enter the Weather Bureau after graduation from school knowing what is to be expected of me."

There are a number of specialized service areas available for assignments, such as the Fire Weather Office in Portland, Oregon, which not only makes forecasts to assist in fighting forest fires already under way, but also furnishes the Forest Service with forecasts indicating the probability of such fires. After two summers at the Portland office, Harold W. Bernard, Jr., of the University of Washington, reports: "A fire-weather trainee's job necessarily offers exciting breaks to the routine as it involves everything from flying through forest fires or talking to the press, to tearing fax maps off the machines or flubbing a sentence on short-wave radio. It involves trips into the mountains, hard work when a critical situation develops, eight hours of overtime on a forest fire, and the feeling of being accepted."

More and more young women are entering the meteorological profession. Here are two contributions from these welcome members of the trainee program. Louise Habicht, of the Women's College, University of North Carolina, wrote from the Computation Unit, National Meteorological Center, Suitland, Maryland: "I think that it is the wonderful feeling

(*Continued on page 258*)

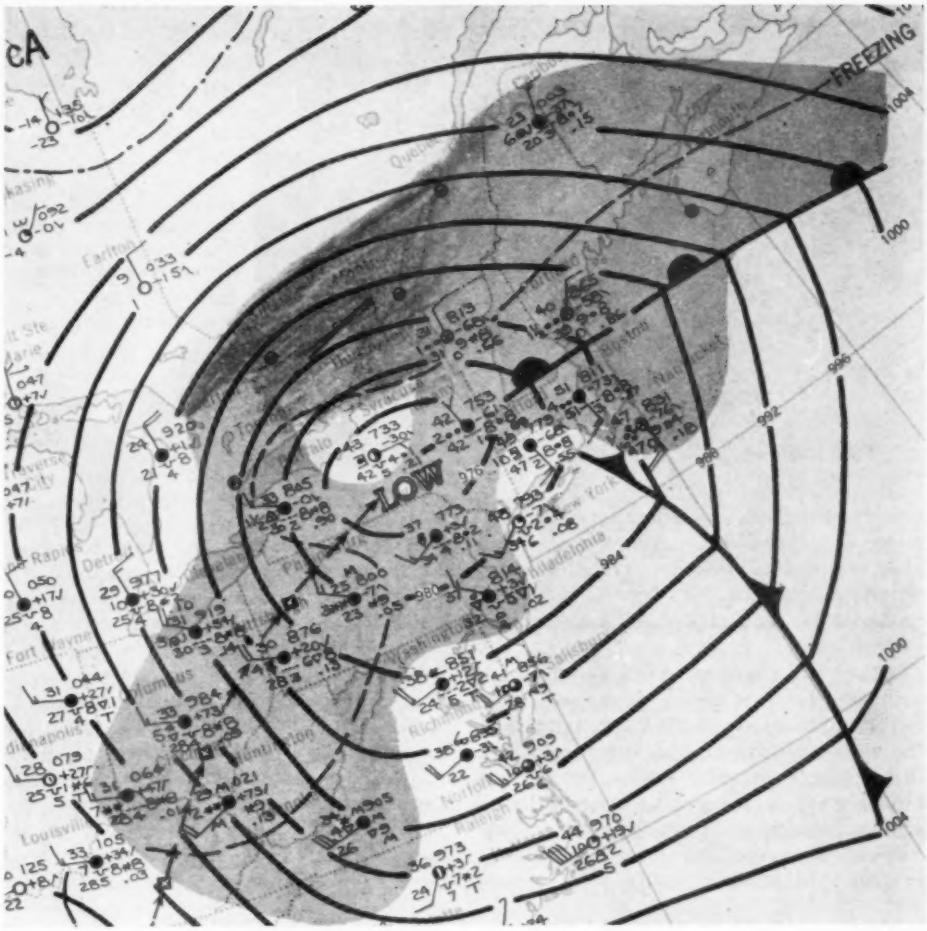


FIG. 1. Surface weather chart at 0100 EST, 26 February 1961, shows storm center on New York-Pennsylvania border with heavy freezing rain falling at Montreal. USWB chart.

The Ice Storm of 25-26 February 1961 at Montreal

F. J. MAHAFFY, *Meteorological Branch, Department of Transport, Canada*

THE Montreal area suffered one of the most damaging ice storms in its history on 25–26 February 1961. Communication and power lines, which are so essential to modern urban life, were almost completely disrupted over large areas for a lengthy period. Many Montrealers were forced to exist for nearly a week in homes without heat, light or cooking facilities, and, in some outlying suburbs, without water. In the areas most seriously affected it finally became necessary to set up emergency shelters where shivering residents were provided with a warm bed and breakfast.

FIG. 2. A residential street in Montreal after the 25–26 February 1961 ice storm. Photo by P. W. Summers.

Damage to public utilities alone was estimated at $3.5 million and total damage probably exceeded $7 million. The storm also served to emphasize the extent to which the modern city resident depends on electrical power.

Although damage proved heavy to trees, advertising signs, telephone lines and other facilities, it was mainly the loss of power and the resulting failure of heating equipment that produced the crisis. That this did not assume major proportions was mainly due to another coincidence by which the storm was followed by several days of relatively mild weather. In addition to the more serious heating problem, many homes were without light, cooking facilities, and even those modern means of communication—telephone, radio and TV. Industries without power were forced to close. Even office and store elevators and escalators refused to function.

Repairs were mainly delayed by the magnitude of the job. There were thousands of broken wires; but in many cases when the wires broke, the poles, now robbed of lateral support, snapped off at the base. In certain areas many distribution lines had to be completely rebuilt before power could be restored. Local repair crews working around the clock were unable to cope with the task

FIG. 3. Telegraph lines and poles near Montreal on 26 February 1961. Photo by P. W. Summers.

and additional crews were called in from neighbouring provinces and from south of the border. Although some central sections of the city (with underground cables) suffered only minor interruptions, it was nearly two weeks before complete service was restored in the full metropolitan area.

WEATHER ANALYSIS

Ice storms occur with moderate frequency at Montreal—freezing rain occurs on an average of about seven days every winter. The damage, however, is usually light. It is interesting to determine why the results of the storm of February 25th–26th were so different.

The damage inflicted resulted directly from a combination of two weather factors—freezing rain and wind. Neither of these were of record proportions or could have been dangerous alone. In this case, wires were first heavily loaded with 1 to 2 inches of ice and then they were subjected to winds of 50 mph with gusts up to 70 mph. This combination would prove too much for even the sturdiest system.

Figure 1 shows the surface weather map at 0100 EST, 26 February 1961, about six hours after freezing rain had commenced at Montreal. A deep low, centered on the Pennsylvania-New York border, had moved from south-central Ohio in the previous 12 hours. Early on the 26th its path curved farther north and eastward, passing about 130 miles south of Montreal at approximately 0600 EST and at 0800 was in central New Hampshire.

The open warm sector of the cyclone can be seen in Fig. 1 showing the polar and maritime air masses involved. In addition, there was a weak remnant of the arctic front over New Brunswick, Maine, and Quebec. The dashed line passing just south of Burlington, Vermont, and near Toronto, Ontario, is the surface isotherm of 32° F. at 0100 EST.

Figure 5 is a cross-section of the lower atmosphere from Albany, New York, to Maniwaki, Quebec (about 100 miles northwest of Montreal) at 1900 EST, 25 February. The temperature aloft over Montreal is typical of a freezing rain situation—a layer of warm air with temperatures above freezing sandwiched between layers of colder air. The temperature reached a maximum of about +36.5° F at 5,000 ft., the top of the transition zone through the maritime warm front. Total thickness of the above-freezing layer was approximately 3,000 ft. A recent study by the Department of Meteorology at McGill has suggested that the thickness of this layer, rather than the thickness of the cold layer below, is the factor which determines whether the precipitation reached the ground as freezing rain or ice pellets. This is based on calculations showing that raindrops must fall through a considerable depth of sub-freezing air before completed freezing takes place. On

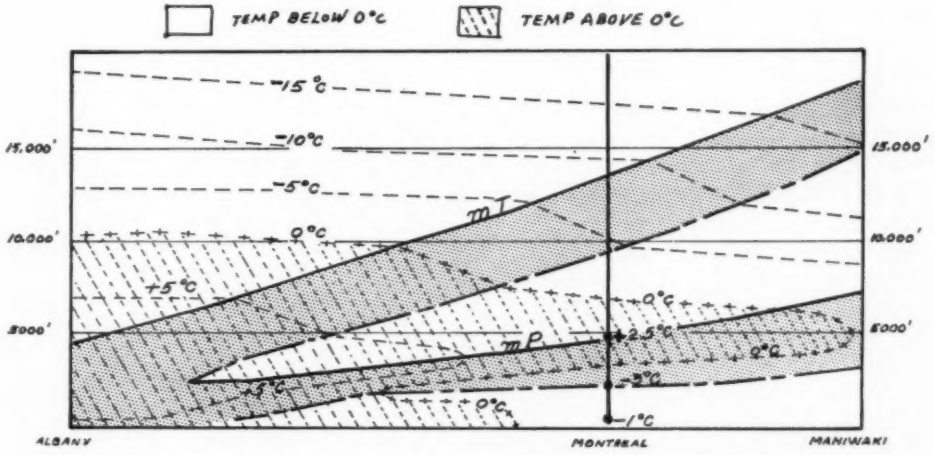


FIG. 4. Cross-section of the lower atmosphere from Albany, N. Y. to Maniwaki, P. Q., at 1900, 25 February 1961.

the other hand, particles which consist partly of ice and partly of water will freeze quickly. Freezing rain will, therefore, occur at the surface when the depth of warm air aloft is sufficient to allow complete melting of the snow particles falling through from higher levels.

PRECIPITATION

Figure 5 is a map of eastern Ontario and southern Quebec showing the amounts of freezing rain reported by all stations within the area affected. The accuracy of these reports, of course, is questionable since freezing rain is difficult to measure. In addition several of the climatological stations shown report only total precipitation every twelve hours and in these cases an arbitrary adjustment has been made to eliminate the amount of snow or ice pellets which followed or accompanied the freezing rain.

AREA OF DAMAGE

Figure 5 indicates that the freezing rain covered a belt about 60 miles wide extending in a WSW-ENE direction along the St. Lawrence Valley almost parallel with the path of the low to the south. The central area is based on reports from power companies indicating the area of maximum damage was centered over Montreal Island. This coincides fairly closely with the area reporting one inch or more of freezing rain. To the north of this area, precipitation was also heavy but a greater part occurred as ice pellets or snow, while to the south surface temperatures were above freezing.

A precipitation of 1.24 inches was reported from Cornwall, Ontario, in the southwest corner of the map, but Cornwall is not indicated as lying within the area of maximum damage. A possible explanation may be indicated by the existence of a maximum temperature of 33° F in the period 1830 to 0800 at this climatological station.

COMPARATIVE RECORDS

A check on past records indicates at least one previous comparable storm on 29–30 December 1942. In this case the total amount of freezing rain (1.54 inches at Montreal Airport) was even greater, but the resulting damage was less. The difference can be found in two factors—the maximum wind following the 1942 storm reached only 35 mph and a majority of homes at that time were still heated by coal furnaces.

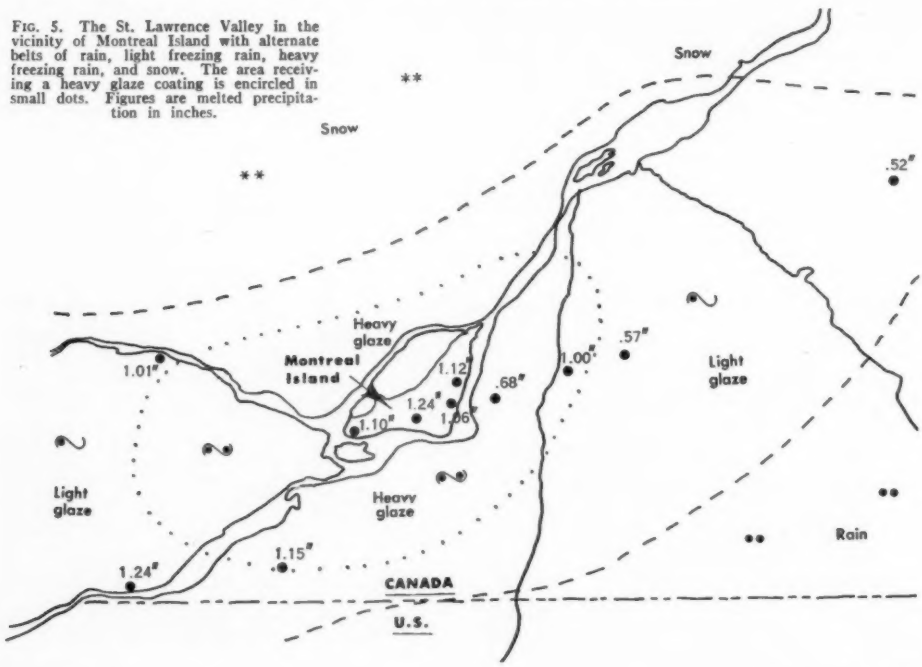


FIG. 5. The St. Lawrence Valley in the vicinity of Montreal Island with alternate belts of rain, light freezing rain, heavy freezing rain, and snow. The area receiving a heavy glaze coating is encircled in small dots. Figures are melted precipitation in inches.

A view of the gear which positions the mirrors permitting the TV camera to scan at five-second intervals the wind speed, wind direction, temperature, barometer, humidity, precipitation, and clock dials.

A Community TV Weather Service

LLOYD A. CALHOUN, *President,*
Hobbs Television Company, Hobbs, New Mexico

WEATHER is a more natural and easier subject of conversation, when friends or strangers meet, than almost any other. Perhaps it was most logical that the management of the Hobbs Television Company of New Mexico, when searching for a truly useful, bonus public service for the subscribers to its Master Antenna Service, should conceive of a 24-hour-a-day local weather reporting facility.

This had never been done before in our industry nor, for that matter, in any other popular medium that we know of.

Equipment was not available in the form which we felt was needed. Most of the components, however, were available, but to assemble them into a usable, automatic system requiring a minimum of maintenance, called for a great deal of original engineering designing.

We at Hobbs Television Company believed that, if the idea were worth pursuing to a reality, several fundamental requirements must be satisfied. Nothing less than the highest quality performance—which meant

A photograph of a TV screen viewing the wind direction dial.

the very best equipment available—should be considered.

It was believed that a complete visual weather system, which would project on each subscriber's television screen the current weather conditions, would not only be interesting, but also of considerable value.

The manner in which this intelligence would be presented called for some original design. It was decided that only one of the six weather dials should be on the screen at any one time because to show more than one, or all of them at once, would not give sufficient clarity of figures and dial graduations to be seen on even the largest standard television screens.

It was, therefore, necessary to design a rotating, step-by-step mechanism to provide for single dial display of each of the six instruments in continuous, automatic operation. An electronics company in Boston engineered and constructed the entire system to our general specifications. Where we had suggested a means for rotating a vidicon television camera to scan the instrument dials arranged in a circle, the engineers preferred an ingenious idea of rotating a set of 45-degree mirrors by means of a Geneva movement which positioned the mirror system alternately in front of each dial for a period of five seconds before moving on to the following dial.

The mechanism is extremely rugged and should give long-term service, relatively trouble-free. The weather instruments are of premium quality, manufactured by Bendix-Friez of Baltimore. The top professional-grade Dage camera system was selected and operates most satisfactorily.

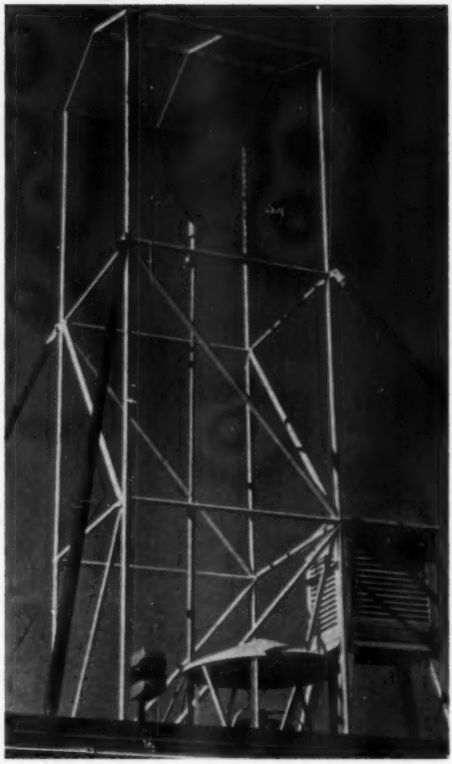
The service, carried on a heretofore unused channel, is complemented on the audio section by a high quality FM music station broadcasting from 0700 to 2400 a program of suitable background music.

Recently we have added an additional, valuable bonus service which is carried on another unused channel and which will further complement the local weather station. Local FAA weather broadcasts are received and fed into this spare cable system channel—thus, providing our subscribers with half-hourly weather reports of conditions along the airways in all directions from Hobbs.

Of even greater importance, the Government weather-radio facility recently placed in service in our area a new weather reporting service called "SIGMET" (meaning significant meteorological development). Severe and potentially hazardous weather within a 200-mile radius of Hobbs will be reported every 15 minutes so long as it exists. These reports primarily intended for assistance to flyers will serve a valuable and possibly life-saving purpose to the citizens of our community who can receive these storm advisories by way of their cable-connected television sets.

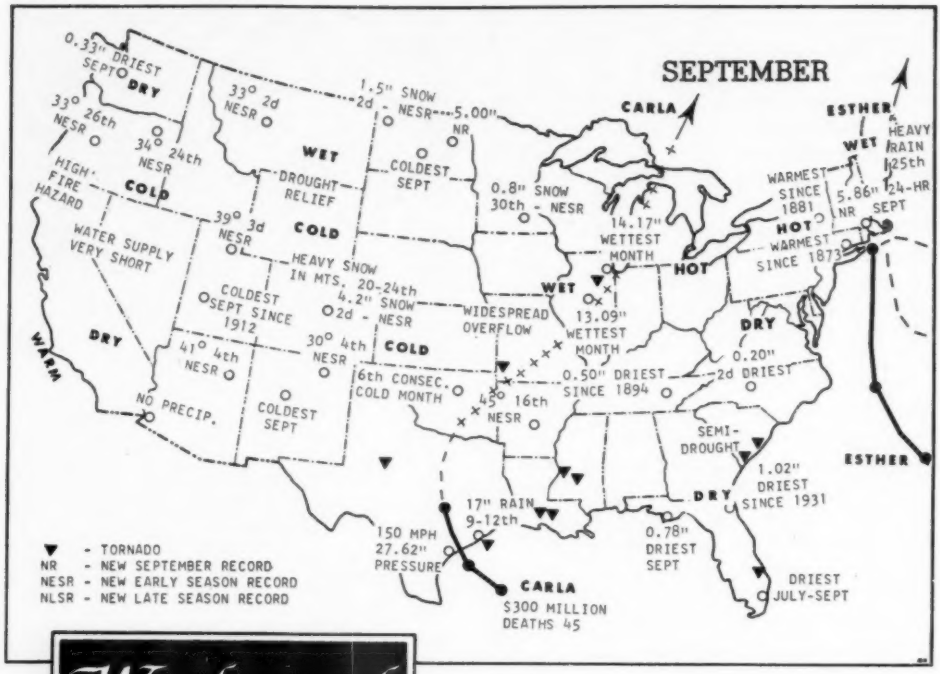
We know that it has been proved locally that a continuous indication of local weather and time is an excellent public service and is greatly more to be desired than a scheduled indication of the same information at various times during the day. One of the thoughts we had about a continous operation was that it would become monotonous. On the contrary, however, practically everyone we ask agrees that the moving, constantly changing images are fascinating to watch.

Recently, we have installed a professional weather station designed by Science Associates. A microbarograph, remote reading thermograph, and remote indicating rain gage display current data in our street-front window, along with an over-size TV screen, so passers may see the complete weather picture at a glance.



View of the exposure of wind instruments and shelter on roof of Hobbs Television Company building. Protective frame is required to shield Aerovane transmitter from ice chunks falling from nearby TV antenna mast.

The position of the TV camera which scans the luminous weather dials behind the screen through the use of a unique set of mirrors.



Weatherwatch

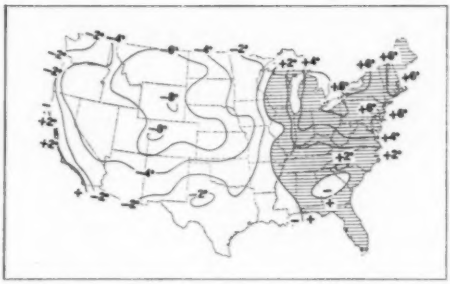
Data by Office of Climatology, USWB.

Autumn Arrives in West—Summer Lingers in East

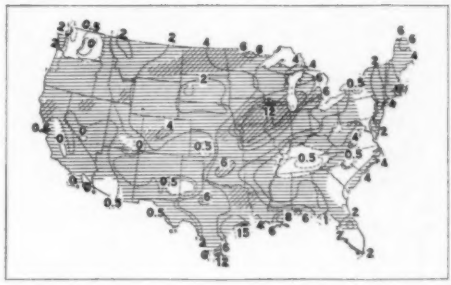
DAVID M. LUDLUM

After a rather dull summer, weatherwise, that featured almost unvarying hot or cool regimes in different parts of the country, the first days of September opened with a meteorological bang! A cold front swept from the North Pacific Ocean into the Northwest to rout the static conditions that had produced record heat persistently since mid-June. The fresh, new air mass moved inland soon after midnight of 31 August accompanied by the following features: a violent wind storm attending the frontal passage tore across the Pacific Coast area north of San Francisco and over the Plateau with the highest September winds ever recorded belting several places —on the 1st and 2d temperatures tumbled from the 90's to near-freezing at many Plateau and Rocky Mountain points—and early on the 3d heavy snows fell over much of the central Rockies and at places in the northern Plains, the earliest snows ever recorded at many stations with long records.

The month continued to make headlines after this illustrious start. Summer-type shower precipitation persisted in the Southwestern States well beyond the usual close of the normal monsoon rainfall season, to cheer conservationists and agriculturalists—Hurricane CARLA, one of the largest and most destructive Gulf hurricanes of the century, smashed ashore in central Texas with at least 45 deaths and damage estimated at $300 million resulting—A swarm of tornadoes, at least 13 were reported officially, dealt death and devastation in CARLA'S northern quadrant in northeast Texas and Louisiana—The dying circulation of CARLA as it moved through the middle Mississippi Valley produced rainfall of unprecedented intensity for the area with many all-time 24-hour marks established—Following the eastward movement of CARLA'S weakening circulatory system, the weather cells across the country once again assumed a semi-fixed position; along the front separating a cold West from a warm East, heavy showers again fell to boost Midwest rainfall totals to maximum September figures—After an extremely warm and pleasant three-weeks in the East, hurricane ESTHER threatened the Atlantic seaboard with a tropical visitation from the 19th to the 22d; and then, after looping seaward and southward, revisited eastern New England on the 25th and 26th—Meantime a second September snowstorm swept the central Rocky Mountains from the 20th to the 24th to



Departure of Average Temperature from normal in degrees Fahrenheit. USWB chart.



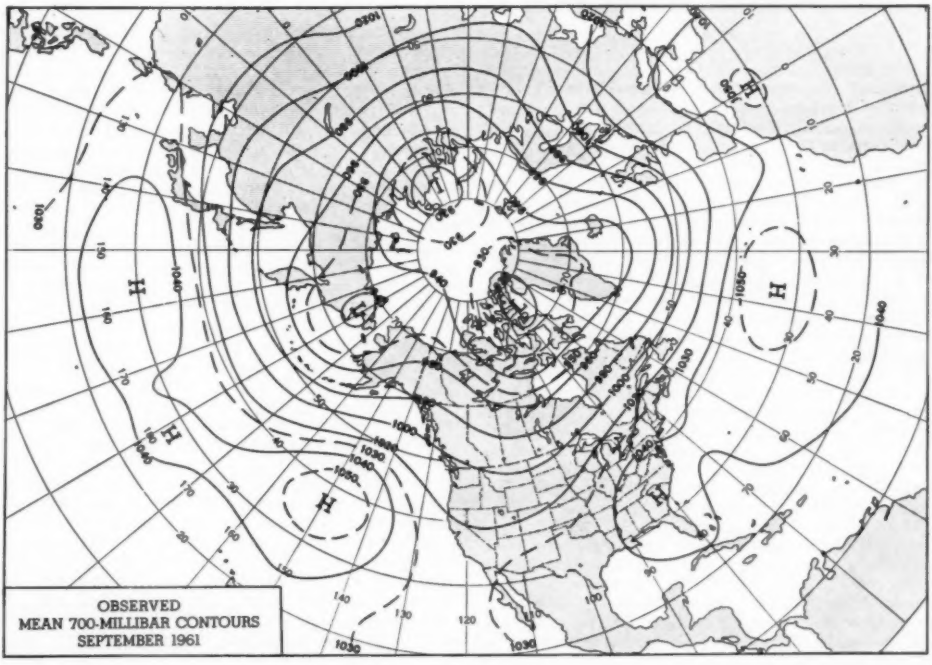
Total Precipitation in inches. USWB chart.

raise snow totals to all-time September marks in Colorado—As a final touch to an unusually cold September in the West, an abnormally early mantle of white spread over low elevations in the northern Plains and the upper Mississippi Valley on the 29–30th.

CIRCULATION—The composite weather charts for September can be readily described in a few words—a wide trough persisted most of the month in the West and a broad ridge overlay the East. A long wave pattern with above average westerly flow prevailed throughout the month with only one short period at the commencement when west-to-east flow dropped below normal. On the upper-air maps at the levels which determine air flow across the continent, the pressure features were extremely well-defined: a broad trough of considerable depth extended from the Canadian Arctic south to Mexico and a vast

(*Continued on page 253*)

The upper-air map below shows the pattern of air flow for September at about 10,000 feet, on which the average weather largely depends. The contours lines represent the mean height of the 700 mb. pressure level. Figures are in tens of feet: 1020 = 10,200 ft., 980 = 9,800 ft., etc. Chart by Extended Forecast Section, USWB.



Weatherwatch

Data by Office of Climatology, USWB.

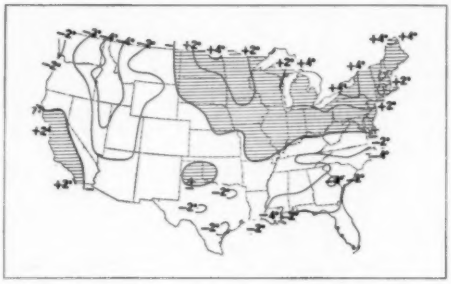
The weather elements in October returned to more customary procedures following the spectacular departures experienced in September. The vast expanse of *much below* normal temperatures in the West forming the principal feature of the mean maps for September disappeared altogether, to be replaced by a *below* area covering most, but not all, of the West. In the East the *much above* regime of September in the Northeast shrank in size and intensity until it occupied only a narrow strip along the border from New York through northern New England. Most of the remainder of the Northeast continued to bask in *above* normal conditions. The principal development, temperaturewise, in October brought cooling to the Gulf States and Southeast, from *near* or *above* normal to *below* normal readings.

No hurricanes invaded the coastline of the United States, nor were deadly tornadoes spawned. There were no nationwide headlines such as CARLA and ESTHER provided in September. Most of the country escaped severe storm activity and enjoyed a mild, pleasant month. There were, however, two sections—the Southwest and the Atlantic seaboard—which felt the lashes of two storm periods apiece, and all of these were of meteorological interest.

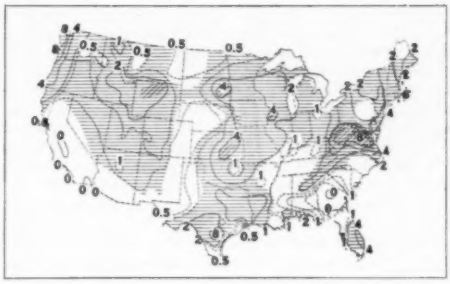
In the Southwest two cold low circulations aloft formed in troughs over the lower Colorado River basin, on the 8th and 28–29th: each generated intense surface cyclones. Very cold air moved southward into the valleys of Arizona and New Mexico and unusually heavy October snows fell over the southern Plateau and central Rockies as the lows moved northeastward. Lander, in central Wyoming at 5563′, caught the brunt of each storm: 18.3″ of snow fell on the 8th and 19.5″ on the 28–29th for its greatest October total. Much heavier amounts fell in the nearby mountains. Around Sheridan, Wyoming, the severest wind and snowstorm in several years blocked roads and downed utilities on the 28–29th when 36 mph winds, drifting snow three to four feet deep, blocked highways. In the Colorado mountains all records for October snowfall were smashed, as they had been in the previous month, to make an excellent start toward storing "white gold" for the 1962 irrigation season.

In the East the two periods of severe weather came within a week of each other, both being associated with cold fronts intensifying as they approached offshore troughs which had served to usher several tropical storms northward during the month. On the 14th a long north-south cold front reached the coast about noon, produced abundant precipitation over the Northeast in merging with a tropical low offshore, and then developed a vigorous circulation as it moved into the Maritime Provinces of Canada. In its wake snow fell to the depth of 6″ to 12″ in New York and New England, the earliest substantial falls during October in 27 years.

Another tropical storm, GERDA, moved northward from Cuba from the 16th to 21st at a slow pace. Staying well offshore, her principal effect was



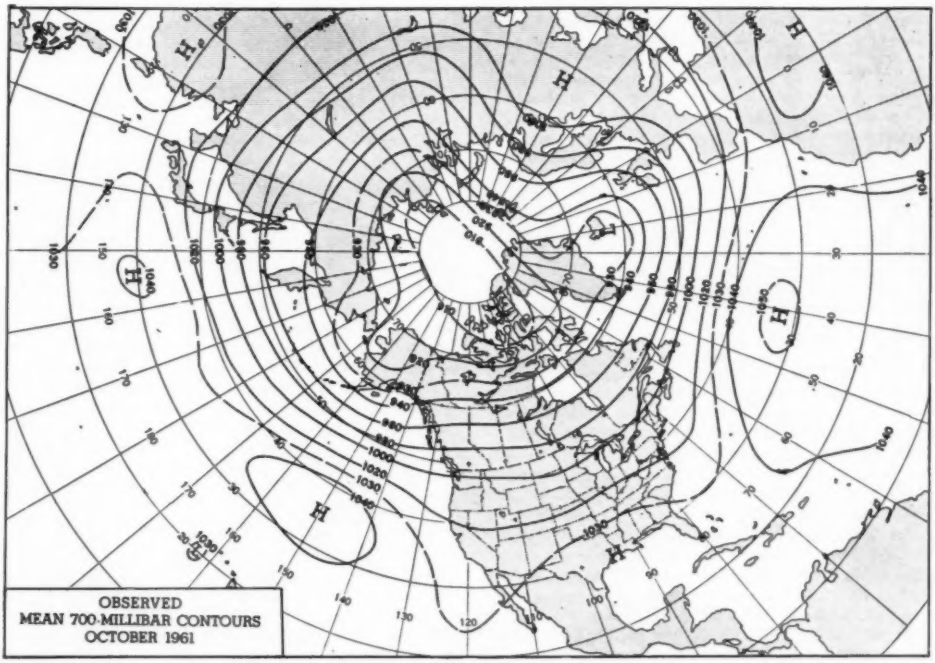
Departure of Average Temperature from normal in degrees Fahrenheit. USWB chart.



Total Precipitation in inches. USWB chart.

instituting unusually high tides all along the Atlantic seaboard, and the high waters continued for five days following the 20th as an intense high-level cyclonic circulation kept winds in a steady counterclockwise spin. A small surface low associated with the upper-air vortex drifted slowly northeastward after drenching central Virginia with record 6-inch-and-more downpours in 24 hours. Not until the 25th did the northeasterly flow along the coast cease so that tides could return to normal. Earlier in the month another tropical storm, FRANCES, had made a stab at the Maine coast, but when about to pass inland, performed an abrupt turn to the northeast carrying the whirl over Nova Scotia where welcome rains descended.

Aside from the Southwest, central Rockies, and the middle and northern Atlantic seaboard, there were no other major storm areas. Additional headlines in October were made by the brief, but intense heat wave in coastal California at mid-month, by the absolute drought in parts of Georgia and Florida, and by the long-continued mild period in the northeastern United States and southeastern Canada. At Toronto it missed by a fraction of a degree being the warmest October in 120 years of record, and other stations on both sides of the border approached their all-time marks. On the cold side, a brief intrusion of polar air dropped the mercury at Duluth on the 1st and 2d to 20° and 17°—both new records for so early in the season.



CIRCULATION—Above normal westerly flow over the middle latitudes of the continent characterized October's atmospheric currents except for one brief period when a strong ridge over the West and a deep upper-air vortex over the East momentarily disturbed the normal west-to-east parade of weather systems. Though the air flow contours were relatively flat over the United States, pressure tended to be lower on the western side of the continent from the Northwest Territories of Canada southward through the Plateau to Lower California and adjacent Mexico. With pressure higher than normal off the northern Pacific Coast, cool maritime air masses rushed into the Northwest and Rocky Mountains behind successive cold fronts to keep temperature means generally below normal. A significant trough during the start of the second week developed a marked low pressure system over the lower Colorado basin. After creating wintry conditions over all the West, the frontal system moved eastward but ran into the resistance of a strong ridge over the East responsible for very mild, almost Indian summer conditions there—the cold front, though entering the Northwest on the 7th, did not clear the Atlantic seaboard until the 15th.

Meantime, in the West a vast building ridge warmed the atmosphere to record October proportions, resulting in new late season marks all the way from Southern California to Saskatchewan and Manitoba.

The next major action of the weather elements lead to the formation of a deep upper-air vortex in a polar trough over Minnesota on the 18th which drifted southeastward off the usual course, all the while increasing in intensity and influence. On the 20th when over North Carolina it caused terrific downpours in central Virginia and heavy snows in West Virginia. It stood south of Nantucket on the 22d and assisted in maintaining the unusual flood tides along the Atlantic seaboard.

There succeeded a period of weak ridges and troughs of short wave length bringing quick changes in daily weather as they sped across the continent.

The final important phase of October's circulation centered in a marked trough that moved in from the North Pacific on the 27th. As had occurred earlier in the month, an intense cyclonic development over the lower Colorado basin spread stormy weather again over all the Southwest. Though the surface low moved off to the northeast with heavy snow and near-blizzard conditions, the upper-air vortex remained over Southern California and Arizona at the month's end to give promise of more interesting weather and abnormal temperatures in the days to come.

CALIFORNIA HEAT WAVE—Central and Southern California were treated to their most intense and widespread mid-autumn heat wave of record. All-time October marks as well as so-late-in-the-season marks tumbled from the 13th through the 19th as an enormous ridge spread its influence over all air current routes leading to the area.

The heat wave centered in the coastal strip between Los Angeles and San Diego, although it eventually extended eastward halfway across the continent as the ridge moved eastward. Long Beach Airport topped the 100° mark on four successive days from the 13th to 16th; the peak figures came with 110° on the 14th and 111° on the 15th. Nearby Los Angeles Airport, close to the ocean, had 106° and 104° on the same days; the former figure was the second highest registered in any month since the station opened in December 1931. Downtown in L.A., with records dating back to 1877, the maximum of 103° closely approached the all-time October high of 104.2° set on the 13th in 1950 and equaled on the 16th in 1958. This heat wave continues the series of exceptionally hot periods experienced in southern California in the past decade.

Southward at San Diego the figure of 107° on the 14th represented the second warmest maximum for any day of any month since the commencement of records in 1872. Northward along the coast as far as Santa Maria 100° readings were posted. In the San Francisco Bay area it was 94° downtown and 95° at the airport, to set new late season records. Inland at Sacramento date records were set on five consecutive days from the 14th through the 19th. Fresno's 99° on the 15th was a new late season mark for that valley location.

The weather map situation during the torrid period found a surface high over the central Plateau which gave California an easterly, continental flow at the surface, with downslope motion from the Plateau and Sierras adding to the thermal capacity of the air mass when it reached the coast. Aloft a ridge with center well north of the Mexican border permitted a southeasterly flow at upper levels into southern California and a southerly flow into central and northern parts of the state. The cooling influences of the Pacific Ocean, usually present at this time of year, were thus excluded for five days, and California underwent its classic example of a mid-autumn heat wave.

SOUTHEASTERN DROUGHT—A severe drought gradually encompassed a large area of the Southeast commencing in mid-September. Excluding the Appalachian highlands, most of the area south of Virginia and the Ohio River and east of the Mississippi River received only 25% to 50% of normal rainfall in September and October. Some areas in central Georgia experienced an absolute drought with no rain, not even a trace, falling from 15 September until 6 November.

The most serious drought area covered most of middle and southern Georgia, southeastern Alabama, and northern Florida. Some of the October totals were: 0.00″ at Macon, Ga., trace at Tallahassee, 0.07″ at Atlanta, 0.08″ at Montgomery, and 0.09″ at Savannah. From Macon: "This was not only the driest October of record, but also the driest month in the history of the station. Never before has there been a calendar month with no precipitation. . . . Cover crops and pastures are in poor condition and danger of field and forest fires is acute." From Tallahassee: "Only a trace of rainfall recorded this month which equals the lowest amount for October." After a moderate rain on 15 September, the Capitol City of Florida did not have a measurable rainfall until 6 November, a total of 51 consecutive days. It was not until 24 November that a soaking rain revived grass and shrubbery.

The dry weather in the fall season facilitated harvest operations, but pastures and small grains were badly in need of moisture throughout the Southeast. Fortunately, rainfall had been above normal previous to the onset of the drought and the water table remained high, so no long term effects of the unusual dryness were expected.

CANADIAN BRIEFS

Compared to normal, the month was cold in the West, warm in the East, and very cold in the southern Arctic. . . . Southern Ontario and Quebec were very dry, as were portions of the Arctic. . . . In British Columbia the first and third weeks were dry and sunny, and the second and fourth weeks dull, wet and stormy. . . . Prince Rupert had 23″ of rain, while at Cape St. James on the Queen Charlotte Islands, there were 22 days during the month with wind speeds in excess of 30 miles per hour. . . . Indian summer conditions prevailed on the Prairies at mid-month with most stations reporting temperatures in the 80s. . . . Temperatures of 83° at Regina on the 15th, and 81° at Winnipeg on the 16th, were records for so late in the season. On 22 October, Regina experienced one of the worst October snow storms on record when 8″ fell in less than 24-hours. . . . During the month Calgary had 15″, and nearby Pincher Creek 30″ of snow. . . . Southern Ontario was exceptionally warm for October. . . . The mean temperature at Toronto came within a fraction of a degree of being the warmest October since observations began in 1840. . . . The St. Lawrence valley was unusually mild and dry for October. Precipitation was above normal in Nova Scotia after many months of sub-normal precipitation. . . . The first cold wave of the season moved over the Maritimes on the 15th, ending an unusually long frost-free season. . . . Hurricane GERDA passed to the southeast of the Maritimes on the 20th and was responsible for excessive rainfall. . . . The month was warm and pleasant in Newfoundland. . . . Temperature extremes in Canada during the month were 88° at Roland, Man., and −40° at Eureka, N.W.T. Heaviest rainfall was 36″ at Stewart, B. C., and the heaviest snowfall was 40″ at Hay River, N.W.T.

September (*Continued from page 249*)

ridge with much above normal pressures in the Gulf of Alaska stimulated a great rush of cold air southeastward from Alaska and western Canada. An intense blocking ridge settled over the northeastern United States and southeastern Canada, astride the normal path of traveling cyclones. Its south-north streamlines over eastern U. S. pulled balmy air masses persistently northward throughout the month.

The presence of trough conditions and cyclonic activity over the Plateau and Rocky Mountains encouraged air flow out of the Canadian Northwest into all the northern border states west of the Mississippi, with the result that all four September weeks averaged below normal and a very large segment of the country west of the Mississippi River had *much below* temperature averages in September. These were the very same areas which had been *much above* in June, July, and August. Seldom does such a drastic circulation and thermal shift occur at this season. Some stations in eastern Montana averaged 24 degrees colder in September than in August!

The intrusion of CARLA into Texas on the 11th changed the weather picture across the country radically, as the western trough moved eastward to the Mississippi Valley to provide the hurricane with an open path northward. An upstream ridge built up in the West, but this soon edged eastward to be replaced by another entering the Pacific Coast on the 16th.

For the next week the western trough remained over the West (to continue the cool regime everywhere west of the Mississippi) and a large northeast-southwest oriented ridge reestablished its hold over the Eastern third of the country (to prolong the mild regime there). It was the eastern extension of this persistent ridge over the Maritime Provinces and the adjacent North Atlantic that encircled the advancing ESTHER and held her entire circulation captive in a pincer for a full week between the 19th and 26th.

In the closing days of the month a more normal western ridge-central trough-eastern ridge system prevailed in place of the single trough-single ridge earlier in the month. An Arctic vortex controlled the circulation across the continent with fast-moving fronts speeding from west to east. Temperature trends, however, in both East and West continued abnormal at unseasonable levels.

The areas of precipitation in September closely reflected the influence of prevailing pressure contours and persistent air flow. Generally heavy precipitation fell in the western trough and along the trough's eastern flank where the sometimes stationary front encouraged convective activity. Light rainfall was experienced under the eastern ridge except in eastern New England where ESTHER'S double visitation raised amounts well above normal. The outstanding instances of excessive precipiattion occurred in connection with CARLA: Bay City measured a storm total at 17.62″ during the storm period when the hurricane smashed ashore and set up a continuing rain pattern from the 9th to 12th; and the still vigorous circulation aloft helped to produce falls of over 8.00″ as far north as eastern Iowa on the 12–13th.

COLORADO COLD & SNOW—September 1961 was one of the coldest and wettest Septembers in Colorado's history. Snow and precipitation totals exceeded previous amounts for period extending back as far as 60 years or more for some stations in and near the mountains.

Moderate to heavy snow fell on the 2d through the 4th in most of the mountain areas and snowfall extended as far east as Denver and Colorado Springs. This was the earliest snow at Denver; the earliest previous with measurable amount in 80 years of record at the City Office occurred on 21 September 1951. Even in many mountain areas, it was the earliest recorded measurable snowfall, or was the heaviest snow ever measured so early in the season.

A second snowstorm on the 20th through the 24th was the heaviest on record for September in many areas in and near the mountains of the northern half of the state. Record heavy snow cover for the season remained on the higher mountain ranges at the end of the month.

This was the second coldest September at Denver since 1873, and the coldest at Grand Junction since 1892. The lowest temperature observed in Colorado was +3° on the 25th at Fraser. The greatest total snowfall was 63.2″ at Climax 2NW (el. 11,300′) and the deepest snow on the ground at one time was 22″ at both Sugar Loaf Reservoir (el. 10,000′) on the 3d and Yampa (el. 7890′) on the 23d.

CARLA'S RAINS—Of the many facets to CARLA'S history, the unusual rainfall pattern deserves attention. The hurricane's approach to the

Texas coastline, as exemplified by the rainfall at Galveston in the right semicircle, were surprisingly light until early afternoon on the 11th when the center was very close to its landfall. Rainfall intensity picked up during mid-afternoon with the greatest hourly rate of 0.95″ between 1600 and 1700 when the center was passing inland about 115 miles to the south-southwest. The rate than slacked off until 2200 when very heavy falls commenced and continued until 0700/12th. Of the 11.65″ falling in 24-hours, 6.92″ was registered between 0001–0700/12th when CARLA'S eye was well to the west and northwest of the station. The grand total for three days rain at Galveston amounted to 15.26″ and the airport measured 16.09″. But Port Arthur, 65 miles to the northeast, had a storm total of only 4.39″ with 2.70″ of this amount falling in 24-hours.

Inland along CARLA'S path the rainfall pattern was very irregular. The 8-inch isohyet covered most of northeast Texas north of Port Lavaca to College Station and then east almost to the Louisiana border. But northward, the large cities close to the path registered the following: Austin 2.89″, Dallas 4.31″, Fort Worth 2.15″, and Oklahoma City 3.62″. In Oklahoma two stations topped the seven-inch mark: Kingfisher 7.36″ and El Reno 7.08″.

CARLA continued to demonstrate her rain-making prowess when many hundreds of miles from the source of her moisture. A long northeast-southwest cold front cutting through the Lower Lakes, across Missouri, to Texas served to usher the remains of the hurricane center northward. Along this front rainfall had been plentiful on the 11th before the tropical storm circulation reached the area, but the additional impetus to atmospheric overturning attending CARLA'S passage over Missouri, Iowa, and Illinois opened the record flood gates.

Kansas City had 5.44″ in 24 hours on the 12–13th and a storm total of 6.30″—St. Joseph, Missouri, 4.46″ and 4.81″—Burlington, Iowa, 6.29″ and 7.47″—Dubuque, Iowa, 5.80″ and 8.04″—Moline, Illinois, 6.29″ and 7.47″—Rockford, Illinois, 5.56″ and 7.11″—Peoria, Illinois, 4.15″ and 6.47″.

The strip of extremely heavy precipitation extended northeastward across Lake Michigan also. Milwaukee had a storm total of 4.16″ and Muskegon, Michigan, 3.07″. Chicago's rainfall from CARLA amounted to 2.63″ in an 8-hour period—of this 2.00″ fell in a 3-hour period around midnight of the 12–13th.

These torrential rains sent streams over their banks from Texas to Wisconsin. The most serious situations developed in the Texas Gulf drainage and in eastern Kansas; in both areas extensive flood damage resulted as new record crests were established. Elsewhere the situations were locally severe, but the run-off was rapid and losses were lighter.

ESTHER—After hurricane ESTHER turned northward in normal fashion off Cape Hatteras, her forward progress decelerated rapidly as she approached the 40°N latitude south of Block Island. Instead of roaring into southern New England as others had done from the same position, ESTHER hesitated on the morning of the 21st, lost her dynamic drive, and later in the day slide sideways off to the east passing just south of Nantucket where the lowest pressure of 29.33″/993.2mb and a one-minute highest sustained wind speed of 40 mph indicated that ESTHER was now well below the hurricane class.

The strong, persistent ridge over the Atlantic seaboard still held fast when ESTHER sought a steering current and a clear channel northward. Though she possessed a distinct cyclonic circulation reaching well above 20,000′, she could not penetrate the defenses of the ridge overlying eastern Canada and was forced southeastward to 65°W on the 23d, southward to 36°N off Cape Hatteras on the 24th, and then circled north again to pass west of Nantucket late on the 25th. Once finally headed northward, ESTHER moved at a normal pace over Massachusetts Bay, into the Gulf of Maine, and then made a land traverse through central Maine and into Canada passing over the mouth of the St. Lawrence River on the 26th.

Hurricane looping is not an unusual phenomenon for tropical storms. George W. Cry in the November *Mariners Weather Log* has called attention to 15 instances of clockwise loops and 23 counterclockwise gyrations charted between 1886 and 1958. ESTHER'S circle occurred farther northwestward than any other observed in that period. A search of Mr. Cry's excellent charts of hurricane tracks for the modern period revealed only one other hurricane, that on 30 September 1894, which approached very close to the New England coast, lost its forward momentum, and failed to penetrate the shoreline.

ESTHER'S two passes at the New England shore furnished two periods of heavy rainfall. The following amounts fell during the first approach on the 21st and during the second on the 25–26th: Block Island, 7.30″ and 2.02″—Nantucket, 1.29″ and 1.60″—Providence, 4.97″ and 1.64″—Blue Hill Observatory (Milton, Mass.) el. 629′, 6.03″ and 2.74″—Boston, 2.80″ and 2.92″—Portland, Me., 1.01″ and 2.55″.

CANADIAN BRIEFS

Summer was prolonged in eastern Canada during September 1961, but abruptly came to an end in western Canada. . . . Temperatures averaged 6 degress below normal in the central Prairies, and 6 degrees above normal in southern Ontario and Quebec. . . . It was the coolest September in two decades on the Prairies, but the warmest September on record in Montreal and Halifax. . . . The national extremes 92° at Caledonia, Ontario, and −25° at Eureka, N.W.T. . . . Three hurricanes affected eastern Canada during the month, BETSY skirted the Grand Banks of Newfoundland, CARLA moved over the Great Lakes and left heavy rain in its wake, and the remnants of ESTHER moved up through the Maritime provinces. . . . Monthly precipitation totals in excess of 8″ were reported in northeastern Ontario as a result of CARLA, but the greatest precipitation in the country was 17.10″ at Ocean Falls on the British Columbia coast. General killing frost came to the eastern Prairies on 23 September, and to the western Prairies towards the end of the month. . . . Summer drought continued through September on the western Prairies, but precipitation was above normal on the eastern grain areas. . . . From 1 April to 30 September, only 4.88″ of rain were reported from Regina, the driest summer season since only 3.88″ fell in 1894. . . . Measurable snow was reported as far south as the international border in Alberta, and temperatures remained continuously below freezing at the extreme northern stations of Alert, Eureka, and Isachsen.

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MAXIMUM-MINIMUM THERMOMETER
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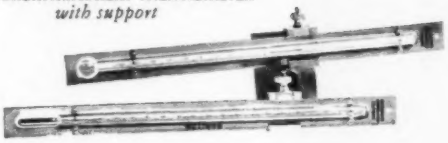

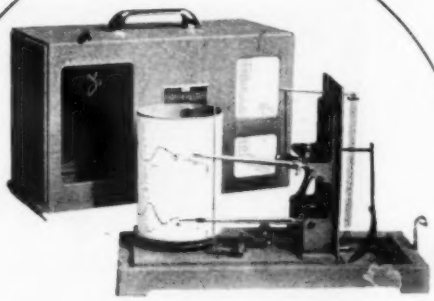

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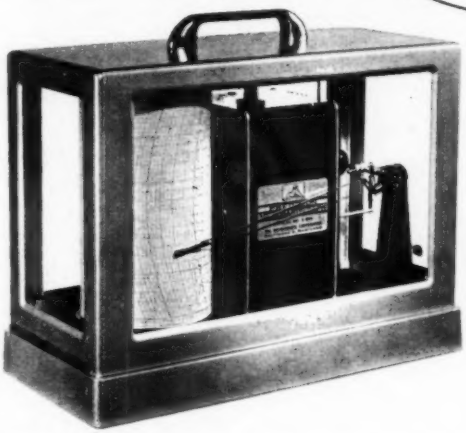

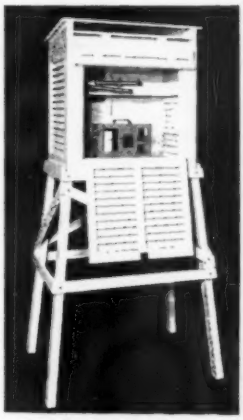

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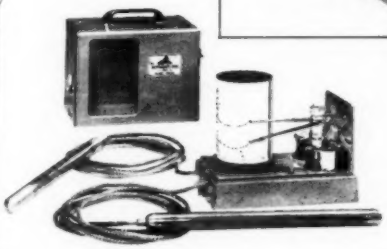
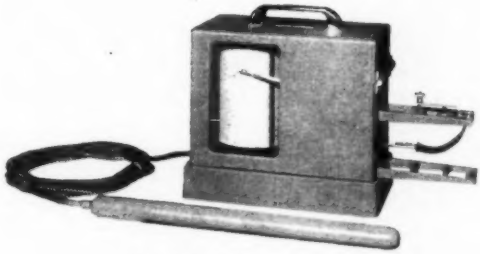


Cat. 5-1135
DUAL SOIL THERMOGRAPH, 2 PEN
cat. no. 5-1100 *single soil thermograph*



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"Ernie" Christie at the WBAB microphone in Babylon, New York.

Retirement Is Rewarding

ERNEST J. CHRISTIE, *Brightwaters, New York*

IT has been said, many times over, that every man should plan something definite for his retirement years. This planning must be in direct ratio to age as well as to physical and mental condition. If one remains active in his career work until he reaches "a ripe old age," then perhaps very little planning will be necessary for retirement will no doubt mean primarily a period of rest and relaxation. On the other hand, if one retires at an early age while in good spirits and in good physical condition, he may even want to plan for a "second" career. I have known men who have done this and I have also known men who have retired to a life of minimum activity—one of these having "enjoyed" twenty years now of just sitting and reading and sleeping.

The idea had been in my mind for several years that I would take advantage of the benefits of U. S. Civil Service retirement plan when I had enough years on the job and the age to do so. I was quite certain that I could even embark upon a new career in the field of private meteorology picking out those portions thereof which would keep me mentally alert and provide enough physical endeavor to make my retirement a rewarding experience. My thoughts were directed also to those aspects of the meteorological profession wherein I might bring some benefit to it by direct application or by planting the seeds of thought in the proper direction. Many of you know that it has been one of my pet themes that business firms and agencies could make weather work for them rather than against them if they attacked the weather problem from the proper point of view—a realistic point of view.

After almost a year now in my retirement status, all of the things I had hoped for have come to pass. Radio broadcasting for a small local radio station gives one the daily routine necessary to keep one on the move, so to speak. It also keeps one mentally alert in a field overflowing with interesting things to talk about. One gets the feeling of belonging to people in a small but important part of the world and gets close enough to them through these radio contacts so that they appreciate what you are trying to do. The personal contacts with listeners become a pleasant "by-product"—such as the visit I had with a father and mother and their son who is a senior in high school this year and who is intensely interested in meteorology, or the

Ernest Christie briefs the staff of the Long Island Lighting Company's Weather Central as Hurricane ESTHER threatens its territory. LILCO photo.

junior high lad who came for some help on a weather project and was tickled when I gave him a couple copies of *Weatherwise;* or Bob Smith who called one day and said: "Ernie, I've got to bring a boat around from Long Island Sound to Bay Shore in the next few days, what day looks best to you?"

I have been fortunate in my association with radio station WBAB, Babylon, New York, which broadcasts on frequencies 1440 AM and 102.3 FM, doing three weather spots each day and a fourth during the boating season. The first of these is at 7:30 in the morning and the others at 12:30 and 4:25 p.m., so you see I was not kidding when I said that this provides the necessary physical activity.

Time has still been available to give me the opportunity to work with a few business firms and other organizations on the relationship of weather to their operations. These ranged from public utilities, to developers of electronic equipment for data measurement and processing, to services and recreation. Needless to say, I was encouraged by the evidence on the part of these organizations to do somethoing constructive about their weather problem or problems.

All of this still leaves me time for "puttering" around the house and lot, for participating in local civic affairs, and for continuing many church-related activities. There is no doubt in my mind that RETIREMENT is a rewarding experience.

ED. NOTE. Mr. Christie concluded a 30 year career in the U. S. Weather Bureau in January 1961. He was meteorologist-in-charge of the New York City office from 1949 to his retirement.

New AMS Publications

1962 will inaugurate a new AMS publication program. The *Journal of Meteorology* will be expanded in scope and be known as the *Journal of the Atmospheric Sciences*. A new *Journal of Applied Meteorology* will fill a long-felt need. The *Bulletin of the AMS* will continue and serve primarily as a news medium of Society and related activities. *Meteorological Monographs* and *Meteorological and Geoastrophysical Abstracts* will continue their missions as in the past. No changes in *Weatherwise* are contemplated except that more educational and guidance material at the secondary school level will be presented. Full details may be obtained at the AMS, 45 Beacon St., Boston 8, Mass.

Cities (*Continued from page 229*)

8. Mitchell, J. M., Jr. The Measurement of Secular Temperature Change in the Eastern United States. *Research Paper* No. 43, U. S. Weather Bureau, Washington, 1961. (80 pages.)
9. Steinhauser, F., O. Eckel, and F. Sauberer. *The Climate and Bioclimate of Vienna (Part II)*. Osterreich Gesellschaft für Meteorologie, Vienna, 1957. (136 pages, in German.)
10. Landsberg, H. E. The Climate of Towns. In: *Man's Role in Changing the Face of the Earth* (W. L. Thomas, Jr., editor), University of Chicago Press, 1956, 584–606.

Weather Bureau

(*Continued from page 240*)

of triumph at a successful check-out that makes the work of programming so rewarding. . . . I feel as though everything that I did was helpful in giving me a total, overall picture of the workings of the Joint Numerical Weather Project, and I am certainly sure that I have never before learned so much within such a short time."

Susan Staley, of Duke University, also had some experience with the computer while working in the Office of Meteorological Research in Washington, D. C.: "Programming was something I had heard a lot about, read a little about, and knew nothing about. It was a subject clouded in mystery and superstition. But I have seen the light—not really very much—just a flicker. For a short while I worked with Jack Ellis (research meteorologist) on a program he was writing to study differences in temperature for different radiation conditions. It was fun as well as educational. I was able to see the IBM 1620 in operation and, after a few false starts, even our program worked out as we wanted."

Based on his work at the Severe Local Storms Research Unit in Washington, D. C., Stanley G. Siegel of Rutgers University wrote a paper entitled *An Anomalous Meteorological Case*. "This research paper materialized primarily as a result of increased curiosity by those who were investigating the enigma of March 31st. Upon completion of one particular area of probing, more interesting aspects manifest themselves. Thus, the compilation of data was not unlike a chain reaction."

Albion B. Taylor, of Brown University, working nearby in the Storm Surge Research Unit, says, "The basic problem facing the Unit is the question of what flooding can be expected, and where, during a hurricane or extra-tropical storm. . . . We gathered data for certain locations and certain periods during the last four years, and applied a statistical analysis using the computers at Suitland, Maryland. . . . Considering the experience and the knowledge I have gained . . . I feel this has been a very profitable summer."

Stephen Berman, of City College of New York, and Robert D. Kurie, of New York University, wrote a technical report entitled *Analysis of Meteorological Information from AIREPS Over the North Atlantic from June 1 to June 10, 1961* while working at the Idlewild International Aviation Unit this summer. Their conclusions were:

"1. The incidence of clear air turbulence during the early summer over the Atlantic Ocean is rather small and apparently restricted to less than severe intensities.
"2. Clouds in the volume of air space above 25,000 feet appear to be not too significant.
"3. Temperature reports from jet aircraft are fairly accurate.
"4. D-factor accuracy appears to be of fair degree only and leaves something to be desired."

Our continuing trainee program is expanding each year. The first year, 1956, there were 17 trainees; last summer there were 150. The general feeling in the Weather Bureau for this younger generation can be summed up in a comment made by one of our supervisors: "By all means keep this man. He is a find!" We are happy to report that 46 of our former student trainees have joined us as professional meteorologists.

The student trainee program in government is part of the Federal Civil Service system. The Civil Service Commission conducts the examinations and sets up registers in a number of academic areas such as physics, mathematics, meteorology, and others. Application forms and information concerning employment opportunities may be obtained at most post offices and college placement offices, or by writing to the Chief, U. S. Weather Bureau, Washington 25, D. C., Attention: Personnel Management Division.

Wind Speed

Wind Direction

Temperature

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Rainfall

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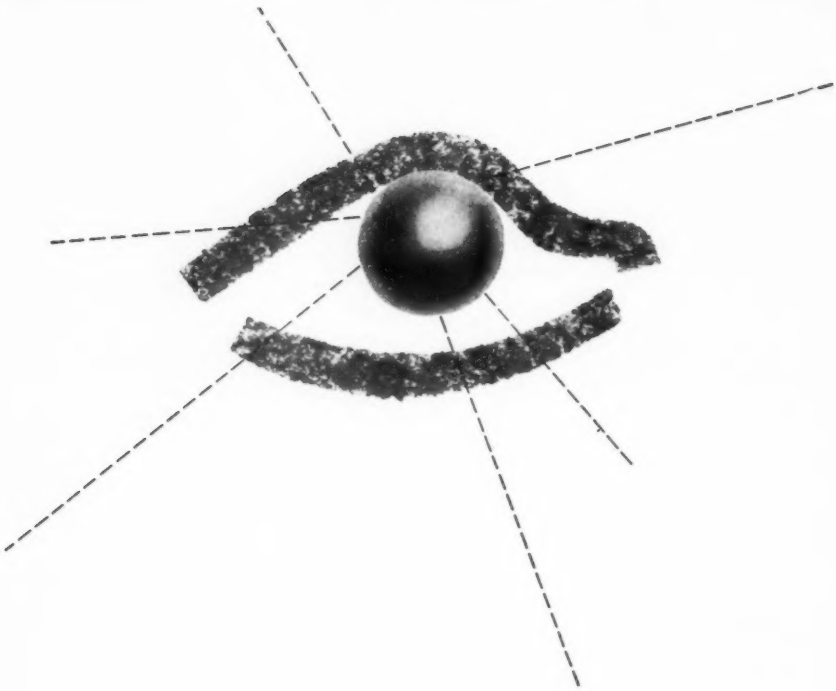

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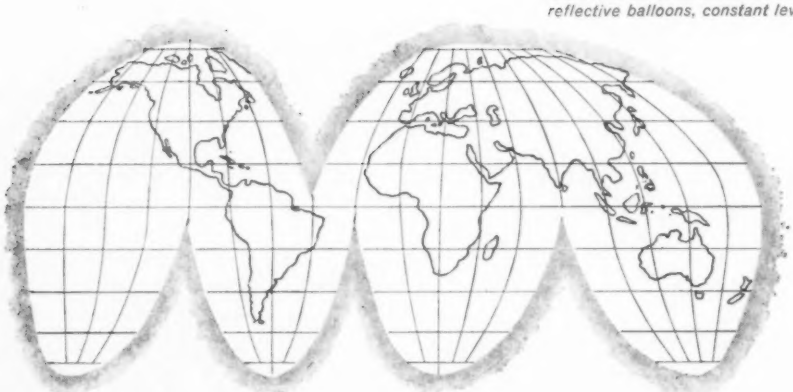
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